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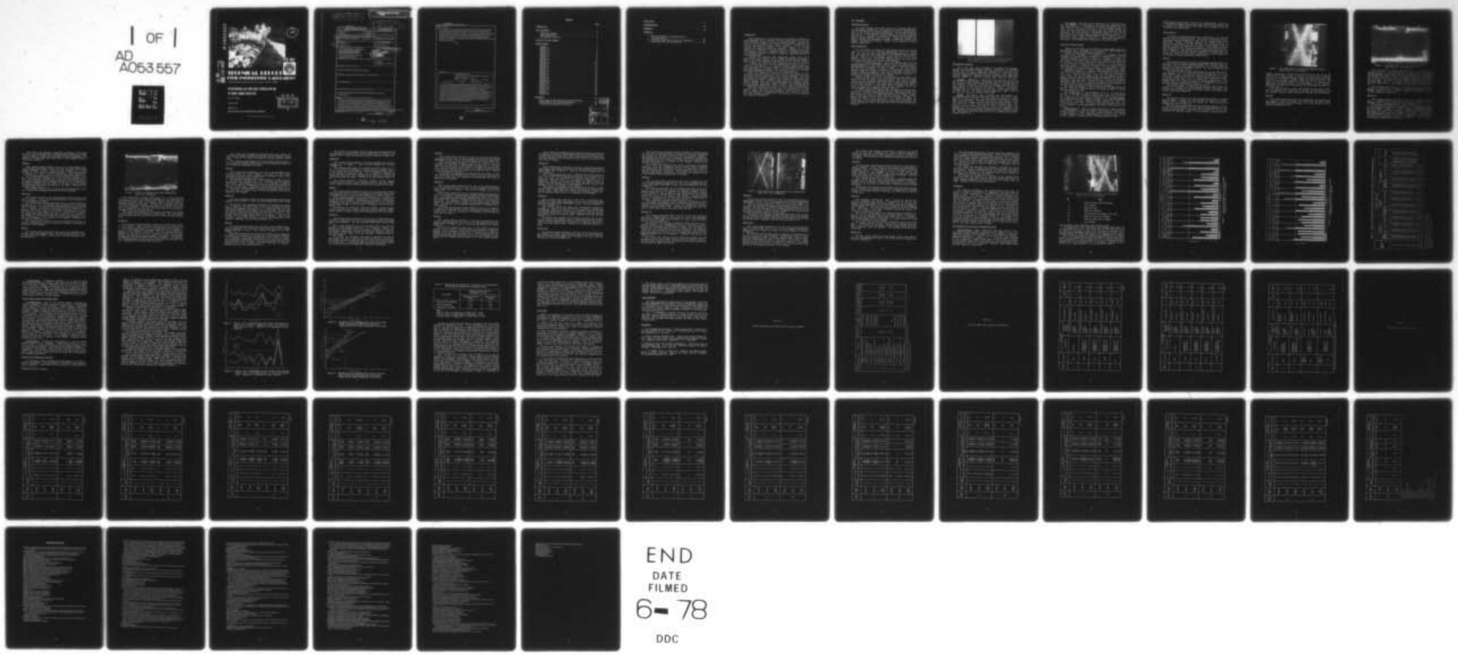

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CIVIL ENGINEERING LABORATORY

Naval Construction Battalion Center, Port Hueneme, California 93043

EFFECTIVENESS OF OVER-RUST PRIMER FOR USE AT NAVAL SHORE FACILITIES

By E. S. Matsui

January 1978

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Various over-rust primers top-coated with government specification paint TT-E-489D were applied over brush-off sandblasted and wire-brushed rusted steel specimens and were exposed 5 yr at three Civil Engineering Laboratory (CEL) marine atmospheric test sites. The performance of the coating system at the CEL test sites was compared with that of the government specification test standard coated over sandblasted, brush-off sandblasted, and wire-brushed steel specimens. The results indicate that a coating system using a superior over

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over-rust primer can provide protection comparable to that of the test standard applied over the sandblasted steel specimens. However, most of the over-rust primers tested provided less protection than the test standard. A test standard coated with a wash primer (Formula 117) provided poorer protection than the same coating system without the wash primer when applied over the rusted steel specimens. Estimating anticipated durability of coating system at one site from data obtained from another site by a regression analysis is also illustrated.

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Various over-rust primers top-coated with government specification paint TT- E-489D were applied over brush-off sandblasted and wire-brushed rusted steel specimens and were exposed 5 yr at three Civil Engineering Laboratory (CEL) marine atmospheric test sites. The performance of the coating system at the CEL test sites was compared with that of the government specification test standard coated over sandblasted, brush-off sandblasted, and wire-brushed steel specimens. The results indicate that a coating system using a superior over-rusted primer can provide protection comparable to that of the test standard applied over the sandblasted steel specimens. However, most of the over-rust primers tested provided less protection than the test standard. A test standard coated with a wash primer (Formule 117) provided poorer protection than the same coating system without the wash primer when applied over the rusted steel specimens. Estimating anticipated durability of coating system at one site from data obtained from another site by a regression analysis is also illustrated.

CONTENTS

INTRODUCTION

Proper preparation of the surface prior to painting is essential to achieve maximum life of a coating. The best quality paint will not perform effectively if applied on a poorly prepared surface. Painting over rusty or poorly prepared steel surfaces is generally regarded as poor practice and should be avoided. Blast cleaning is, by far, the most thorough and effective mechanical treatment. However, it is often impractical or impossible to do this because of environmental and economical reasons, location, or equipment limitation. Maintenance personnel are frequently compelled to resort to cheaper or substandard methods of surface preparation.

Industry has introduced many proprietary primers which can be applied over rusty surfaces and is claiming extraordinary performance. Thus, it has become necessary to appraise the relative merits of many of these products to ascertain their suitability for use by the Navy.

In Fiscal Year 1970, the Civil Engineering Laboratory (CEL) included an investigation of 13 different coating systems using either rust inhibitive or over-rust primers in work sponsored by the Naval Facilities Engineering Command. Six proprietary and seven different specification primers were selected for this investigation.

These rust inhibitive or over-rust primers were applied to wire-brushed and brush-off sandblasted rusty steel test panels and were then top-coated with government specification coating TT-E-489D. The coated test panels were placed on exposure racks at the three CEL marine atmospheric exposure sites: Kaneohe, Hawaii; Kwajalein, Marshall Islands; and Port Hueneme, California. Their performances were compared with the control standard system (MIL-P-15328, TT-P-645, and TT-E-489D) applied to sandblasted-to-white-metal steel test panels exposed simultaneously.

This report presents the results of 5 yr of exposure at the three exposure sites. This report also includes an attempt to devise a procedure to estimate the anticipated durability of a coating at one site from data obtained at another site. The results of 3 yr of exposure were reported in Reference 1.

TEST PROCEDURE

Laboratory Analyses

All paint coatings tested were analyzed to determine composition and some physical properties. The analyses were based on methods specified in the Federal Test Method Standard No. 141 (2); ASTM Standards, Part 20 (3); and the Painting Testing Manual, 12th Edition by Gardner and Sward (4). The physical properties determined included weight per gallon, specific gravity, and consistency. Composition analyses were made to determine the percentage by weight of nonvolatile solids, total pigment, and nonvolatile vehicle. Results of the laboratory analyses appear in Appendix A.

Panel Preparation

All test panels (12 panels for each coating system) were of mild steel, 6 x 12 x 1/8 in., providing approximately 1 sq ft of overall area. The new test panels were washed with methylethylketone to remove any rust inhibitive oily substances on the surfaces, then placed on exposure racks at the Port Hueneme exposure site for 4 wk to allow rusting to take place. During the rusting procedure, the test panels were turned over each week to obtain uniform rusting.

Prior to coating application, six of the rusted panels for each coating system were wire-brushed, washed in water, and then washed in methylethylketone to remove the water; the other six rusted test panels were brush-off sandblasted as shown in Figure 1. All test coating systems, over-rust primers top-coated with government specification paint TT-E-489D, were applied to both sides of the panels by means of an automatic horizontal-transverse paint spraying machine, resulting in a uniform paint thickness for each set of panels.

Coating systems coated over the wire-brushed rusted panels were identified with the letter "R" to differentiate them from the systems coated over the brush-off sandblasted panels. The control standard coating system was applied over white metal sandblasted steel (System 13), as shown in Figure 1. After being coated, the panels were dried or cured as required for the particular coating. Appendix B lists the coating systems, their thickness, and their sources.

To allow evaluation of adhesion loss and coating blistering associated with corrosion resulting from abrasion damage that exposes bare metal and to accelerate the weathering process, two diagonal cuts were made through the coating to expose the steel substrate. These scribes, made in the shape of an "X" on one side of the coated test panel, extended about 1-3/8 in. from each corner. Four coated test panels, two scribed and two unscribed, from each coating system were exposed to the marine atmosphere at each of the three test sites, with the scribed side facing up.

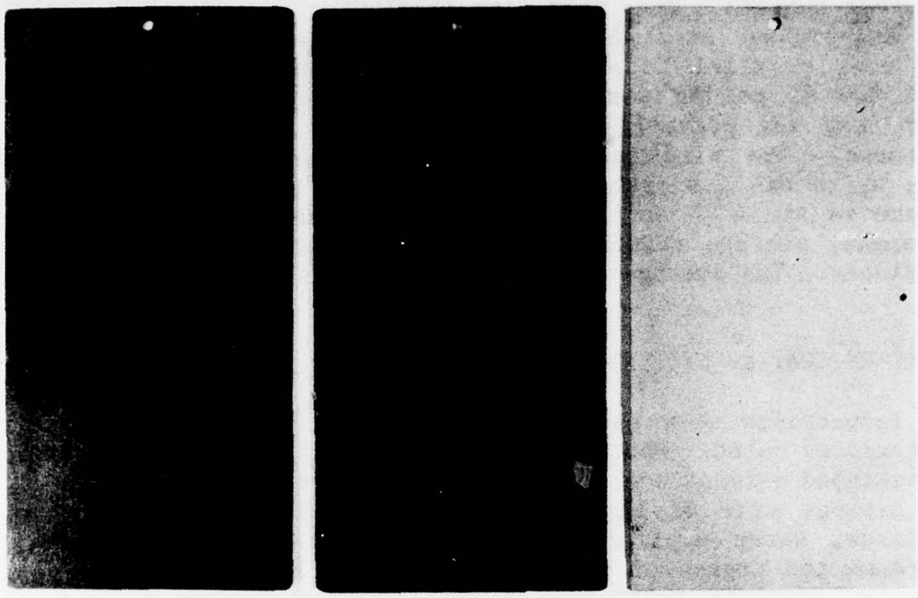

Figure 1. Three different states of rusted surface preparations (from left to right): wire-brushed, brush-off sandblasted, sandblasted-to-white-metal.

CEL Exposure Locations

Each of the three marine atmospheric environments (Port Hueneme, Kaneohe, and Kwajalein) presents different combinations of weathering factors such as rainfall, temperature, humidity, solar radiation, wind, and salt spray in varying intensities and duration. Thus, these three different geographical locations provide an opportunity for simultaneous exposure studies of identical coatings under differing conditions.

Kwajalein. Kwajalein is located near the center of the tropical zone at $8^{o}44'$ north latitude. The exposure racks are about 100 ft from the surfline at high tide and hold the test panels at a 45-deg angle to the horizontal, facing the prevailing east-northeast wind that carries large amounts of salt spray to the panels. Rainfall is plentiful, averaging over 10 in./mo during 8 mo of the year. Total annual rainfall is about 105 in. The annual average temperature range is 81F to 83F, and wind velocity is between 8 and 21 mph.

Kaneohe. The exposure racks at Kaneohe face east-northeast into the prevailing wind and are about 200 ft from the surf and up a knoll about 40 ft above sea level. The test panels are placed at a 45-deg angle to the horizontal. The wind often carries small amounts of fine sand, which has a slight abrasive action on the coating surfaces. This test area is at a $21^{o}21'$ north latitude near the northern edge of the tropical zone (the Tropic of Cancer is $23^{o}27'$ north latitude). The Kaneohe test site has a slightly greater variation in temperature than does Kwajalein with average annual temperature ranging between 73F and 79F. The monthly rainfall varies from 1 to 9 in.; annual total rainfall averages about 43 in.

Port Hueneme. This test site is located on a pier where the specimens are exposed at a 45-deg angle to the horizontal, facing west. The pier runs parallel to a north-south rock jetty (breakwater) which is about 300 ft to the west of the pier. The surf breaks against this jetty, and the prevailing west wind carries ocean spray onto the test specimens. The wind carries a considerable amount of fine sand and dust, which has a slight abrasive action on the coating surfaces. Port Hueneme is at 34°7' north latitude (10°40' north of Tropic of Cancer). The annual average rainfall is about 12 in. and arrives during 5 mo in the winter. The average annual temperature is from 51F to 65F.

RATING OF COATING SYSTEMS

Inspections were made of the exposed coatings annually and their performances rated. Photographs of the coatings were taken semiannually. The assigned ratings are tabulated in Appendix C.

Ratings were assigned by CEL personnel in accordance with ASTM Standards, where applicable. A numerical rating system was used for recording the degree of protection given by a coating. A rating of 10 indicated complete protection, a rating of 0 indicated no protection. For example, if the metal substrate had lost protection over 10% to 20% of its surface the coating was given a rating of 8. In this report, a protection rating of 7 indicates coating failure; this rating indicates that maintenance or recoating was necessary. E in the Appendix C tabulation indicates the rating was based on coating performance at the edges.

Chalking is evident as a removable powder evolving from the coating film at, or just beneath, the surface. To determine the chalking rating, a 4-in. stroke is made with a clean, dry cloth across the surface of a coating. The spot of powder on the cloth is compared with photographic reference standards (ASTM Designation D659-44); the degree of chalking is then rated from 10 (no powder on the cloth) to 2 (the powder completely covers the spot). Because the amount of chalking present on the coating film at the rating time was affected by recent rainfall, the recorded rating represents a maximum rating for chalking.

The degree of rusting is rated in accordance with ASTM Designation D610-43. Both Type I (rusting without blistering) and Type II (rusting with blistering) are rated.

The blister size is also designated 10 to 2: 10 indicates no blisters, 8 indicates the smallest blister easily seen with the unaided eye, and 6, 4, and 2 represent progressively larger sized blisters. Size 2 represents a blister diameter of about 1/4 in. Blister frequency is reported as dense (D), medium dense (MD), medium (M), and few (F), where "dense" represents complete surface coverage and "few" only occasional blisters. Thus, a rating of 2/M would represent blisters of 1/4-in. diameter, covering approximately one-fifth to one-quarter of the surface.

Undercutting is a type of coating deterioration in which adhesion of the coating film to the metal panel is destroyed by the formation of corrosion products. In most cases these products would be rust inasmuch as steel panels are used. Undercutting most frequently occurs at the scribes or edges of the panels where coating protection is least.

Undercutting in these areas is rated 10 (no undercutting), or 8, 6, 4, 2, representing progressively greater areas affected by the undercutting. A rating of 5 would indicate that 50% of the designated area was affected by the undercutting.

RATING RESULTS

The results obtained during the 5 yr of weathering at the three CEL exposure sites are presented below. Three years of exposure at Kwajalein usually provide enough data so that inferior coating systems can be identified. However, long-term exposures are normally required to better identify superior coatings, and after 5 yr of exposure it may be possible to select the best or the superior coating system that will have continued to give satisfactory protection to the steel test specimens at Kwajalein. The coatings that fail during these additional 2 yr can be ranked in protective quality, depending on whether they fail during the fourth or fifth years at Kwajalein and on the condition of the coatings at Kaneohe during these same periods.

System 1

This system consisted of one coat of government specification, rust inhibitive red lead and lead chromate alkyd primer (TT-E-485E, Type II), and three coats of alkyd enamel (TT-E-489D). The coating system was applied over brush-off sandblasted panels. The total average dry-film thickness was 6 mils (0.006 in.).

This specification coating system gave fair to very good protection (rating of 8 to 9+) to the unscribed test specimens for 3 yr at the three exposure sites. The panels at Kwajalein failed after 4 yr, primarily due to heavy blistering and rusting along the edge, while panels at Kaneohe failed after 5 yr in a similar way. The panels at Port Hueneme showed only slight rust along the edges throughout the 5 yr of exposure and were rated good (rating of 9-). Chalking of the top coats was rated medium to medium heavy (ratings of 6 to 4).

The scribed panels at Kwajalein and Kaneohe failed during the second year of exposure and in Port Hueneme during the third year. The failures were attributed to dense blistering, rusting, and tuberculation in the scribed areas (Figure 2).

System 1-R

This system consisted of the same government specification coatings used in System 1, except that the coatings were applied over wire-brushed panels as indicated with the letter "R". The total dry-film thickness was 6 mils (0.006 in.).

This coating system provided much less protection against corrosion than had the coating applied over the brush-off sandblasted panels. The coating system gave fair to good protection (rating of 8- to 9) on the unscribed test specimens during 3 yr of exposure at Kaneohe and Port

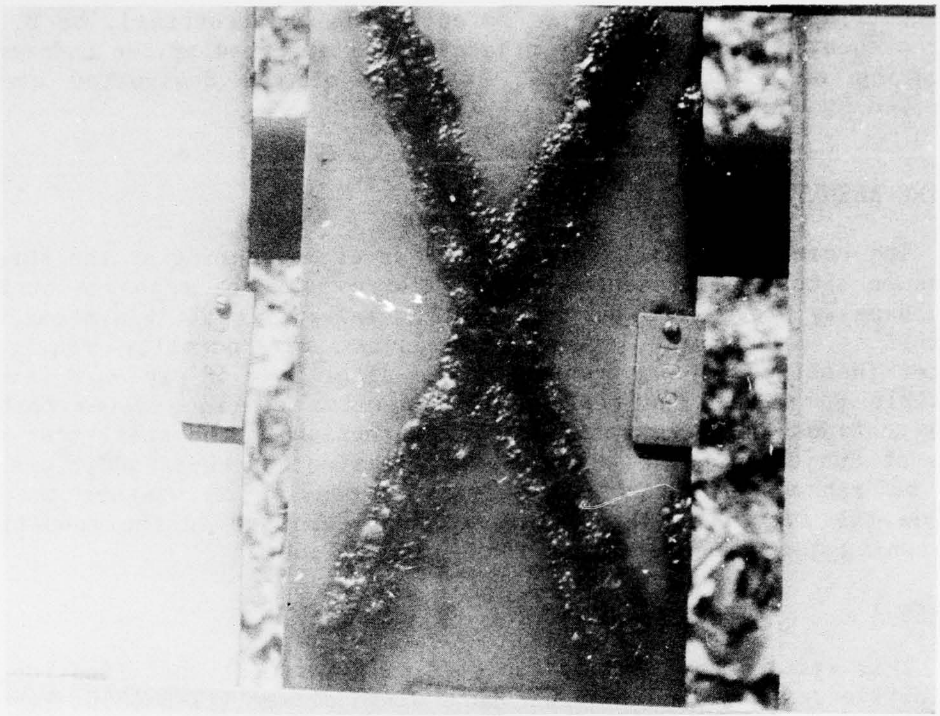

Figure 2. TT-E-485E primer over brush-off sandblasted System 1 panels after 2 yr at Kwajalein.

Hueneme, respectively. However, the panels failed at the end of the second year in Kwajalein and the end of the fourth year at Kaneohe (rated 7) due to heavy blistering, rusting, and some undercutting along the edges of the panels. Figure 3 shows this type of failure. The panels at Port Hueneme showed only slight rust at the edges and were given good protection (rating of 9-) throughout 5 yr of exposure. Chalking of the coatings at Port Hueneme was rated medium (rating of 6) at the end of 5 yr.

This system failed at scribed areas during the first year of exposure at Kwajalein, the second year at Kaneohe, and the third year at Port Hueneme because of heavy blistering, rusting, and tuberculation.

System 2

This system consisted of one coat of government specification red lead phenolic primer (TT-P-0086e) and three coats of alkyd enamel (TT-E-489D), giving a dry-film thickness of 6.5 mils (0.0065 in.) over brush-off sandblasted panels.

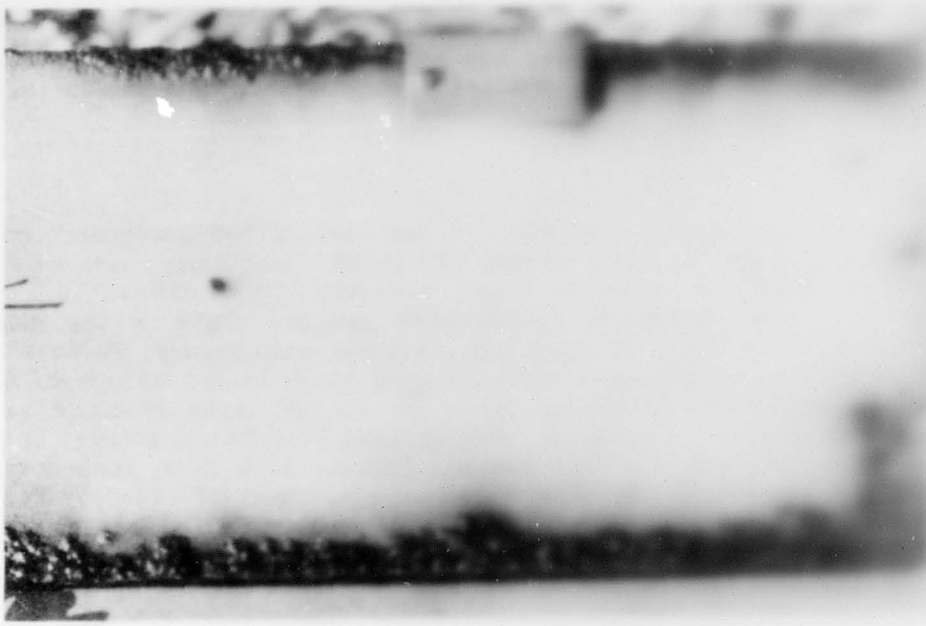

Figure 3. TT-E-485E primer over wire-brushed System 1-R panel after 2 yr at Kwajalein.

This specification coating system gave fair to good protection (rating of 8 to 9) to the unscribed test specimens for [illegible] yr at [illegible] and Port Hueneme, respectively. The test specimens failed at Kwajalein and Kaneohe during the third and fifth years of exposure, respectively, due to heavy blistering, rusting, and undercutting along the edges of the test panel. The panels at Port Hueneme showed only slight rust along the edges after 5 yr of exposure and was rated fair (8). Chalking of the top coats was rated medium to medium heavy (ratings of 6 to 4).

This coating system failed at the scribed area during the first, second, and third years of exposure at Kwajalein, Kaneohe, and Port Hueneme, respectively, due to heavy rusting, blistering, and tuberculation along the scribed areas.

System 2-R

This coating system is the same as that used in System 2, except that it was applied over wire-brushed test panels. The total dry-film thickness of this coating system was 6.5 mils (0.0065 in.).

This coating system gave fair to good protection (rating of 8 to 9) to the unscribed test specimens during the 3 yr of exposure at Kaneohe and Port Hueneme. However, it failed in Kwajalein and Kaneohe during the second and fifth year of exposure, respectively, because of heavy blistering and rusting along the edges of the panels. The panels at Port Hueneme showed slight rust along the edges after 5 yr of exposure and were in fair condition (rating of 8). Chalking of the top coats was rated medium to medium heavy (rating of 6 to 4).

The scribed test specimens at Kwajalein and Kaneohe failed during the first year of exposure due to heavy blistering, rusting, and tuberculation along the scribed areas and edges of the test specimens. This system also failed along the scribed areas at Port Hueneme during the third year of exposure.

System 3

This coating system consisted of one coat of the government specification alkyd zinc chromate primer (TT-P-645) and three coats of alkyd enamel (TT-E-489D) to give a total dry-film thickness of 6.5 mils (0.0065 in.) over brush-off sandblasted panels. This system differs from System 14 in that it does not include wash primer, Formula 117.

This coating system gave fair to good protection (ratings of 8+ to 9+) to the unscribed specimens for 3 yr at the three exposure sites. The system continued to provide fair to good protection during the 5 yr of exposure at Kaneohe and Port Hueneme (rating of 8 to 9, respectively). The panel at Kwajalein was near failure at the end of the 5 yr because of considerable blistering and rusting at the edges. Chalking of the coatings ranged from 6 to 4.

This coating system failed at the scribed area during the second year at Kwajalein and Kaneohe and third year at Port Hueneme.

System 3-R

This system consisted of the same government specification coating used in System 3. Total dry-film thickness was 6.5 mils (0.0065 in.) over wire-brushed test panels.

This specification coating system gave fair to very good protection (rating of 8 to 9+) to the unscribed test specimens for 3 yr at Kaneohe and Port Hueneme. The test specimen at Kaneohe failed during the fourth year of exposure, but failed at Kwajalein during the second year of exposure. The entire surface of the specimen at Kwajalein was covered with blisters of sizes ranging from 8 to 6. Larger blisters, rusting, and slight undercutting along the edges caused the test specimen to fail (Figure 4). The system continued to provide good protection (rating of 9) throughout 5 yr of exposure at Port Hueneme. Chalking of the top coats was rated as 6 to 4.

The coating systems failed at the scribe during the first year of exposure at Kwajalein, during the second year at Kaneohe, and during the third year at Port Hueneme.

System 4

This coating system consisted of one coat of the government specification lead silico chromate alkyd primer (TT-P-615d) and three coats of alkyd enamel (TT-E-489D) to give a total dry-film thickness of 6.0 mils (0.006 in.).

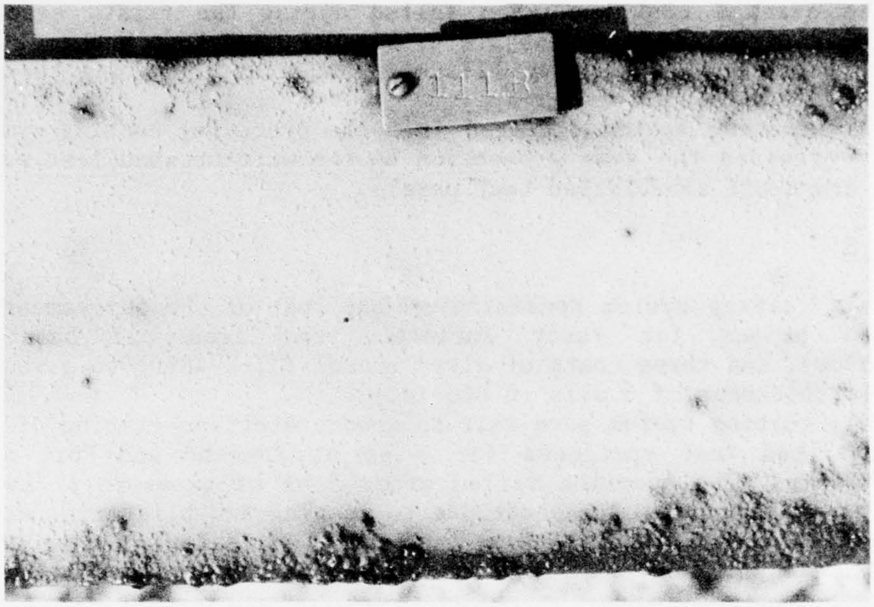

Figure 4. Blisters on System 3-R (TT-P-645 primed panel) after 2 yr at Kwajalein.

This specification coating system gave fair to good protection (rating of 8 to 9) for unscribed test specimens for 3 yr at Kaneohe and Port Hueneme exposure sites, respectively. However, the panel failed in Kwajalein during the third year of exposure due to rusting, blistering, and undercutting along the edges. The test panel at Kaneohe also failed after 4 yr of exposure. The system continued to provide fair protection at Port Hueneme and was rated fair (8) at the end of 5 yr of exposure. Chalking of the top coats was rated 4.

The scribed test specimens at Kwajalein and Kaneohe failed during the first and second years of exposure, respectively. The test specimen at Port Hueneme was near failure at the end of the third year of exposure.

System 4-R

This coating system consisted of the same specification coatings used in System 4. Total dry-film thickness was 6 mils (0.006 in.).

This coating system gave fair to very good protection (rating of 8 to 9+) to the unscribed test specimens during the 3 yr of exposure at Kaneohe and Port Hueneme, respectively. The test specimens failed in Kwajalein at the end of the 3 yr of exposure because of blistering, rusting, and undercutting along the edges of the panel. The specimens at Kaneohe also failed during the fifth year of exposure. The panels at Port Hueneme remained in good condition (rating of 9) at the end of the 5 yr. Chalking of the top coats was rated 6 to 4.

The scribed test specimens failed during the first, second, and third year of exposure at Kwajalein, Kaneohe, and Port Hueneme, respectively, because of the heavy blistering and rusting along the scribed areas.

This coating system differed from the preceding coating systems in that it provided the same protection to the wire-brushed test panels as to the brush-off sandblasted test panels.

System 5

This coating system consisted of one coat of the government specification primer for rusty surfaces, red iron oil base primer (TT-C-530a), and three coats of alkyd enamel (TT-E-489D) to give a total dry-film thickness of 6 mils (0.006 in.).

This coating system gave fair to good protection (rating of 8 to 9) for unscribed test specimens for 3 yr at Kaneohe and Port Hueneme, respectively. The specimen failed after 3 yr of exposure at Kwajalein and 4 yr of exposure at Kaneohe due to rusting and blistering along the edges of the test panel. Chalking of the top coats was rated 6 to 4.

The scribed test specimens at Kwajalein and Kaneohe failed during the second year of exposure while it failed during the third year of exposure at Port Hueneme.

System 5-R

This coating system consisted of the same government specification coatings used in System 5. Total dry-film thickness was 6 mils (0.006 in.).

The unscribed test specimens at Kwajalein failed after the second year of exposure. The entire surface of the test specimen was covered with blisters ranging in size from 8 to 6. Larger blisters, rust, and undercutting formed along the edges of the test specimen. The unscribed test panel at Kaneohe failed during the third year of exposure. This coating system has given good protection (rating of 9) to the test specimen at Port Hueneme during the 3 yr of exposure. This coating continued to provide fair protection (rating of 8+) during the 5 yr of exposure. Chalking of the top coats was rated 6 to 4.

System 6

This coating system consisted of one coat of the government specification alkyd red lead primer (MIL-P-17545) and three coats of alkyd enamel (TT-E-489D) to give a total dry-film thickness of 6.75 mils (0.00675 in.).

This coating system gave fair protection (rating of 8) at Kwajalein and Kaneohe and good protection (rating of 9) at Port Hueneme during the 3 yr of exposure. The coating system failed after 4 and 5 yr of exposure at Kwajalein and Kaneohe, respectively, due to blistering, rusting, and undercutting along the edges. The system continued to provide fair protection (8) at Port Hueneme during the fifth year of exposure. Chalking of the top coats was rated 6 to 4.

The scribed test specimens failed at Kwajalein and Kaneohe during the second year of exposure and at Port Hueneme during the third year of exposure due to heavy rusting and blistering along the scribed area.

System 6-R

This coating system consisted of the same government specification coatings used in System 6. The dry-film thickness was 6.75 mils (0.00675 in.).

This coating system gave fair to good protection (rating of 8 to 9-) to the unscribed specimens at Kaneohe and Port Hueneme, respectively, during the 3 yr of exposure. The test specimens failed after 2 yr of exposure at Kwajalein, after 3 yr of exposure at Kaneohe and during the fourth year at Port Hueneme due to blistering, rusting, and undercutting along the edges. Chalking of the top coats was rated 6 to 4.

The scribed specimens at Kwajalein, Kaneohe, and Port Hueneme failed during the first, second, and third years of exposure, respectively, because of heavy rusting and blistering along the scribed areas.

System 7

This coating system consisted of one coat of proprietary red lead fish oil primer and two coats of government specification alkyd enamel (TT-E-489D) to give a total dry-film thickness of 6.0 mils (0.006 in.).

This coating system gave fair to good (rating of 8 to 9) protection to the unscribed specimens at Kaneohe and Port Hueneme, respectively, during the 3 yr of exposure. The specimen failed after 3 yr of exposure at Kwajalein and 5 yr of exposure at Kaneohe because of rust and blistering along the edges of the test panel. Chalking of the top coats was rated 6 to 4.

The scribed test specimens at Kwajalein, Kaneohe, and Port Hueneme failed during the first, second, and third years of exposure, respectively, because of heavy rusting and blistering along the scribed areas.

System 7-R

This coating system consisted of one coat of the same proprietary red lead oil primer and two coats of the government specification alkyd enamel used in System 7. The total dry-film thickness was 6 mils (0.006 in.).

This coating system has given fair protection (8) to the unscribed specimen at Port Hueneme after the 5 yr of exposure. However, the system failed during the first and second years of exposure at Kwajalein and Kaneohe, respectively, because of dense blistering and rusting of the surface and near edges of the test specimens. Chalking of the top coats was rated 6.

The scribed test specimens failed both at Kwajalein and Kaneohe during the first year of exposure and failed during the third year at Port Hueneme because of heavy rusting, rust stain, and blistering along the scribed area. A considerable amount of blistering was also evident on the entire surface of the specimens at Kwajalein and Kaneohe.

System 8

This coating system consisted of one coat of proprietary alkyd red lead primer and two coats of the government specification alkyd enamel (TT-E-489D) to give a total dry-film thickness of 6.0 mils (0.006 in.).

This coating system has given fair protection (rating of 8) to the unscribed test specimen at Kaneohe while it has given an excellent protection (rating of 10) at Port Hueneme throughout the 5 yr of exposure. The test specimen failed after 4 yr of exposure at Kwajalein due to blistering, rusting and heavy undercutting along the edges. Chalking of the top coats was rated 8 to 4.

The scribed test specimens failed during the second year of exposure at Kwajalein and Kaneohe because of heavy rusting, blistering, and rust stain, while the test specimen failed during the third year of exposure at Port Hueneme.

System 8-R

This coating system consisted of one coat of the same proprietary red lead alkyd primer and two coats of the government specification alkyd enamel used in System 8. Total dry-film thickness was 6.0 mils (0.006 in.).

This coating system gave fair to very good protection (rating of 8 to 9) to the unscribed test specimens at Kaneohe and Port Hueneme during the 3 yr of exposure. However, the specimen failed after 1 yr of exposure at Kwajalein because of medium dense blisters and rusting over the test panel. The specimen at Kaneohe failed after 4 yr of exposure because of large blistering, rusting, and deep undercuttings along the edges. The specimen at Port Hueneme remained good (9) throughout the 5 yr of exposure.

The scribed test specimen failed during the first year of exposure at Kwajalein and Kaneohe due to heavy rusting and blistering along the scribed areas. The test specimen at Port Hueneme failed during the third year of exposure.

System 9

This coating system consisted of one coat of proprietary zinc chromate alkyd primer and two coats of the government specification alkyd enamel (TT-E-489D) to give a total dry-film thickness of 6.0 mils (0.006 in.).

This coating system has given fair to near perfect protection (rating of 8, 9, and 10-) to the unscribed test specimens at Kwajalein, Kaneohe, and Port Hueneme, respectively, during the 5 yr of exposure. Chalking of the top coats was rated 6 to 4. This system was the only coating system which gave excellent protection to both brush-off sandblasted and wire-brushed unscribed panels at the Port Hueneme exposure site.

The scribed test specimens failed during the second and third year of exposure at Kwajalein and Kaneohe because of heavy rusting and blistering along the scribed areas. Edge rusting was heavier at Kwajalein. The test specimen at Port Hueneme was near failure at the end of the third year of exposure.

System 9-R

This coating system consisted of one coat of the same proprietary zinc chromate alkyd primer and two coats of the government specification alkyd enamel used in System 9. The total dry-film thickness was 6.0 mils (0.006 in.).

This coating system gave fair to excellent protection (ratings of 8- to 10) to unscribed test specimens during the 3 yr of exposure at the three test sites. The unscribed test specimen failed after 4 yr of exposure at Kwajalein and 5 yr of exposure at Kaneohe because of blistering, rusting, and undercutting along the edges of the test panels. The test specimen was in an excellent condition (rating of 10-) throughout the 5 yr of exposure at Port Hueneme.

The scribed test specimens failed during the second year of exposure at Kwajalein and Kaneohe due to heavy blistering and rusting of the scribed areas. Edges were also rusting and blistering at Kwajalein. The test specimen failed after 3 yr of exposure at Port Hueneme.

System 10

This coating system consisted of one coat of proprietary zinc chromate-iron oxide vinyl alkyd primer and two coats of the government specification alkyd enamel (TT-E-489D) to give a dry-film thickness of 5.25 mils (0.00525 in.).

This coating system has given fair and excellent protection (ratings of 8 and 10-) to the unscribed test specimens at Kaneohe and Port Hueneme, respectively, during 5 yr of exposure. The test specimen at Kwajalein failed after 4 yr of exposure due to blistering, rusting, and undercutting mostly along the edges. Chalking of the top coats was rated 6 to 4.

The scribed test specimens failed during the second year of exposure at Kwajalein and Kaneohe, while it failed during the third year of exposure at Port Hueneme because of heavy rust, blistering, and tuberculation along the scribed areas. Rusting of the edges was light in all cases.

System 10-R

This coating system consisted of one coat of the same proprietary zinc chromate-iron oxide vinyl alkyd primer and two coats of the government specification alkyd enamel used in System 10 to give a dry-film thickness of 5.25 mils (0.00525 in.).

The unscribed test specimens failed at Kwajalein and Kaneohe during the first year of exposure because of moderate to heavy rust accompanied by blisters over the entire surface of the test specimens (Figure 5). The specimens were rated 6 and 7 at Kwajalein and Kaneohe, respectively. The system has given fair protection (rating of 8) to the unscribed test specimen during the 5 yr of exposure at Port Hueneme. Chalking of the top coats was rated 6 to 4.

The scribed test specimens also failed at Kwajalein and Kaneohe during the first year of exposure because of heavy rusting accompanied by blisters along the scribed areas as well as other parts of the surface and edges of the test panels. The specimens were rated 4 and 5 at Kwajalein and Kaneohe, respectively. The scribed test specimens failed at Port Hueneme during the second year of exposure.

System 11

This coating system consisted of one coat of proprietary lead silico chromate phenolic primer and two coats of the government specification alkyd enamel (TT-E-489D) to give a dry-film thickness of 5.5 mils (0.0055 in.).

This coating system gave fair to excellent protection (rating of 8 to 10) to the unscribed test specimens at Kwajalein, Kaneohe, and Port Hueneme during the 3 yr of exposure. This system continued to provide fair protection at Kaneohe and excellent protection at Port Hueneme through the entire 5 yr of exposure. The specimen at Kwajalein failed after 4 yr of exposure due to blistering, rusting and undercutting at the edges. Chalking of the top coats was rated 4 to 6.

The scribed test specimens failed during the second year of exposure at Kwajalein and Kaneohe, while it failed during the third year of exposure at Port Hueneme because of heavy rust, blistering, and tuberculation along the scribed areas. Rusting of the edges was light compared to the scribed areas at the time of the failures.

System 11-R

This coating system consisted of one coat of the same proprietary lead silico chromate phenolic primer and two coats of the government specification alkyd enamel used in System 11 to give a dry-film thickness of 5.5 mils (0.0055 in.).

The unscribed test specimen at Kwajalein failed during the 3 yr of exposure because of rust accompanied by blisters on the entire surface. Rusting and blistering along the edges were heavy. The test specimen at Kaneohe was lost during the third year of exposure but was rated fair (rating of 8) at the end of the second year of exposure. The system has given good protection (rating of 9) to the unscribed specimen at Port Hueneme throughout the 5 yr of exposure. Chalking of the top coats was rated 6 to 4.

The scribed test specimen failed at Kwajalein, Kaneohe, and Port Hueneme during the first, second, and third years of exposure because of the heavy rust, blistering and tuberculation along the scribed areas. Rusting along the edges was moderate.

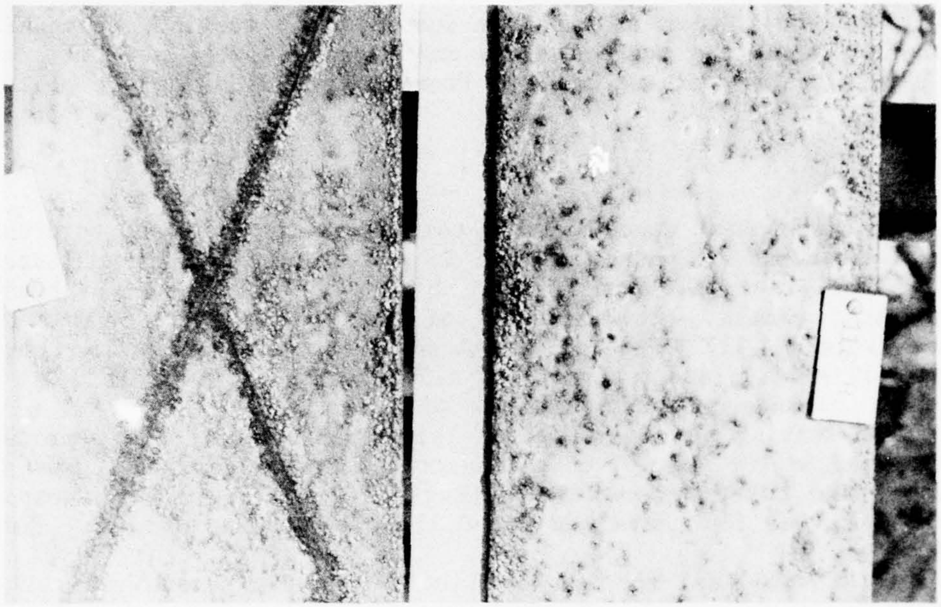

Figure 5. Dense blistering accompanied by rust of System 10-R panel after 1 yr at Kwajalein.

System 12

This coating system consisted of one coat of proprietary long oil alkyd primer and two coats of the government specification alkyd enamel (TT-E-489D) to give a dry-film thickness of 5.85 mils (0.00585 in.).

This coating system has given fair protection (rating of 8) to the unscribed test specimens at Kaneohe and Port Hueneme during the 5 yr of exposure. The test specimen failed at Kwajalein during the third year of exposure because of heavy rusting accompanied by blistering and undercutting along the edges of the test panel.

The scribed test specimens failed during the second year of exposure at Kwajalein and Kaneohe and during the third year at Port Hueneme because of the heavy rusting, blistering, and tuberculation mainly along the scribed areas. Chalking of the top coats was rated 6 to 4.

System 12-R

This coating system consisted of one coat of the same proprietary long oil alkyd primer and two coats of the government specification alkyd enamel used in System 12 to give a dry-film thickness of 5.85 mils (0.00585 in.).

The unscribed test specimens failed at Kwajalein and Kaneohe during the first and second year of exposure, respectively, because of heavy rusting accompanied by dense blistering along the edges. Rusting accompanied by blistering was light at the center of the panel. Slight undercutting and peeling were also observed at Kwajalein. The coating system has given fair protection (rating of 9) to the unscribed test specimen at Port Hueneme during the 5 yr of exposure.

The scribed test specimens failed both at Kwajalein and Kaneohe during the first year of exposure due to heavy rusting accompanied by blistering along the scribed areas and edges, as well as the center of the panels. The specimen at Port Hueneme failed during the third year of exposure.

System 13

This government specification coating system was used to prepare a control standard. Control System 13 was prepared on sandblasted-to-white-metal steel test panels instead of over wire-brushed or brush-off sandblasted panels. It consisted of one coat of vinyl butyral wash primer Formula 117 (MIL-P-15328B), one coat of alkyd zinc chromate primer (TT-P-645), and two coats of alkyd finish (TT-E-489D). The total dry-film thickness was 7.25 mils (0.00725 in.).

This coating system has given fairly good to excellent protection (ratings of 8+, 9- and 10) to the unscribed test specimens at Kwajalein, Kaneohe, and Port Hueneme, respectively, during the 5 yr of exposure. Chalking of the top coats was rated light to moderately heavy (ratings of 8 to 4).

The scribed test specimens failed during the second year of exposure at Kwajalein and during the third year at Kaneohe and Port Hueneme because of the heavy rusting, blistering, and tuberculation along the scribed areas.

System 14

The government specification control coating was applied over brush-off sandblasted test panels. It consisted of one coat of vinyl butyral wash primer Formula 117 (MIL-P-15328B), one coat of alkyd zinc chromate primer (TT-P-645), and two coats of alkyd finish (TT-E-489D) as used in System 13. The total dry-film thickness was 6.25 mils (0.00625 in.). This system is the same as System 3 except that Formula 117 primer was not used in the latter.

This coating system gave fair to good protection (ratings of 8-, 8 +, and 9-) to the unscribed test specimens exposed at Kwajalein, Kaneohe, and Port Hueneme, respectively, during the 3 yr of exposure. This coating system continued to provide fair to good protection (rating of 8- to 9-) during the 5 yr of exposure.

The scribed test specimen failed at Kwajalein during the second year of exposure because of heavy rusting and blistering along the edges. The scribed test specimen at Kaneohe failed during the third year of exposure, while the specimen at Port Hueneme failed during the fourth year.

System 14-R

The same coating system as used in Systems 13 and 14 was applied over the wire-brushed test panels. The total dry-film thickness was 6.25 mils (0.00625 in.).

This coating system has given the least protection compared to all other coating systems described previously. Both scribed and unscribed test specimens at Kwajalein failed during the first year of exposure because of heavy rusting, accompanied by blistering, and rust stains along the scribed areas, edges, and other parts of the panels (Figure 6). Protection of the scribed and unscribed specimens were rated as early failure (ratings of 4 and 6, respectively). Chalking of the top coats was rated 4.

The scribed and unscribed test specimens at Kaneohe also failed during the first year of exposure because of rusting and blistering of the specimens. However, the corrosion was less extensive than that at Kwajalein. The protection of the system was rated 5 and 7, respectively. Chalking of the top coats was rated 6.

The scribed and unscribed test specimens at Port Hueneme failed during the third and fourth year of exposure respectively because of heavy rusting accompanied by blistering along the scribed areas and edges. Chalking of the top coats was rated 8.

DISCUSSION

The relative performance of the coating systems during the 5-yr period at Kwajalein and Kaneohe is summarized in the bar graphs of Figures 7 and 8, respectively. Scribed and unscribed panels are presented together. The solid bars indicate the years of exposure until the coating systems failed. The broken bars in the figures indicate the relative probability of longer protection after 5 yr for those systems that did not fail. The extent of the broken bars reflects subjective and conservative judgments based on the condition of the coating systems at the time of the final inspection at the end of 5 yr. Therefore, it does not necessarily indicate the exact number of years the protection will continue; but, rather, it indicates minimum years of protection the coating can be expected to provide. Actual service lives provided by the coating systems at the three CEL exposure sites and conservatively estimated service lives of the coating systems that did not fail during the 5 yr of exposure are presented in Table 1. An attempt to use regression analysis to derive estimates of the anticipated durability of a coating system using an over-rust primer and the same topcoat at Port Hueneme from data obtained from Kwajalein will be made in the latter part of this report based on data of Table 1.

System Applied Over Brush-off Sandblasted Panels

Unscribed Panels. Figure 7 shows that only three of the 13 over-rust primer coating systems, along with control System 13, were providing satisfactory protection beyond the 5 yr of exposure at Kwajalein. These were Systems 3, 9, and 14, all of which were zinc chromate-pigmented alkyd primers. Systems 2, 4, 5, 7, and 12 failed at the end of 3 yr of exposure. Figure 8 shows that 8 of the 13 over-rust primer coating systems, along with control System 13, were providing satisfactory protection after 5 yr of exposure at Kaneohe. These eight systems and their types are listed below:

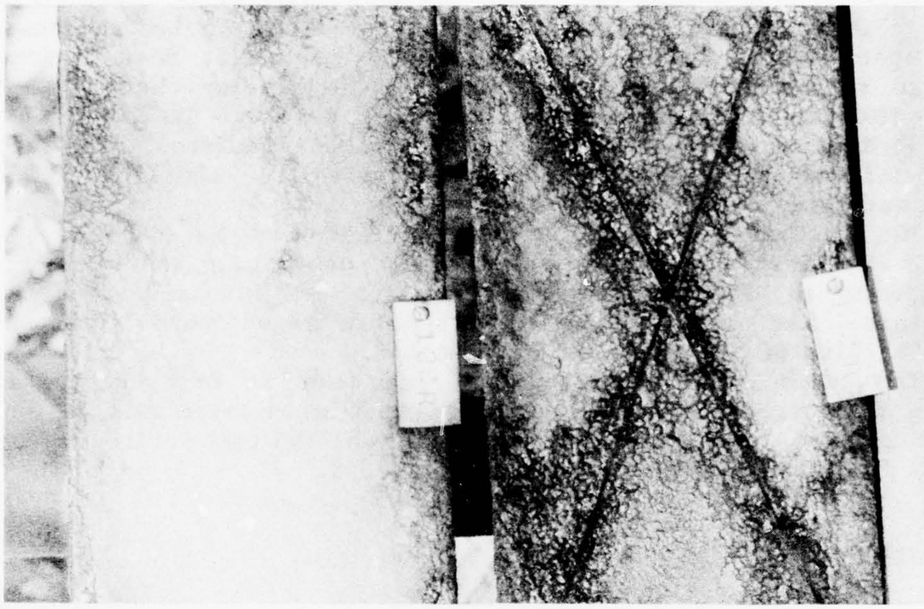

Figure 6. System 14-R (TT-P-645 primed over wire-brushed panels) after 1 yr at Kwajalein.

No.	Type
1	alkyd red lead and lead chromate
3	zinc chromate
8	alkyd red lead
9	alkyd zinc chromate
10	vinyl alkyd zinc chromate, iron oxide
11	phenolic lead silico chromate
12	alkyd red lead silico chromate
14	zinc chromate

Control System 13 also contained a zinc chromate primer.

Coating System 9, with a proprietary zinc chromate alkyd primer and total thickness of 6.0 mils, was giving the best protection after 5 yr of exposure at Kwajalein as well as at the other two exposure sites. The only system performing slightly better than System 9 was the control standard System 13, which was applied over sandblasted test panels.

All 13 coating systems on brush-off sandblasted panels and control System 13 have provided satisfactory protection to the unscribed panels for a minimum of 3 yr and an average of 4.6 yr at Kwajalein and for a minimum of 4 yr and an average of 5.9 yr at Kaneohe. Average projected service life at Port Hueneme is 9 yr, as indicated in Table 1.

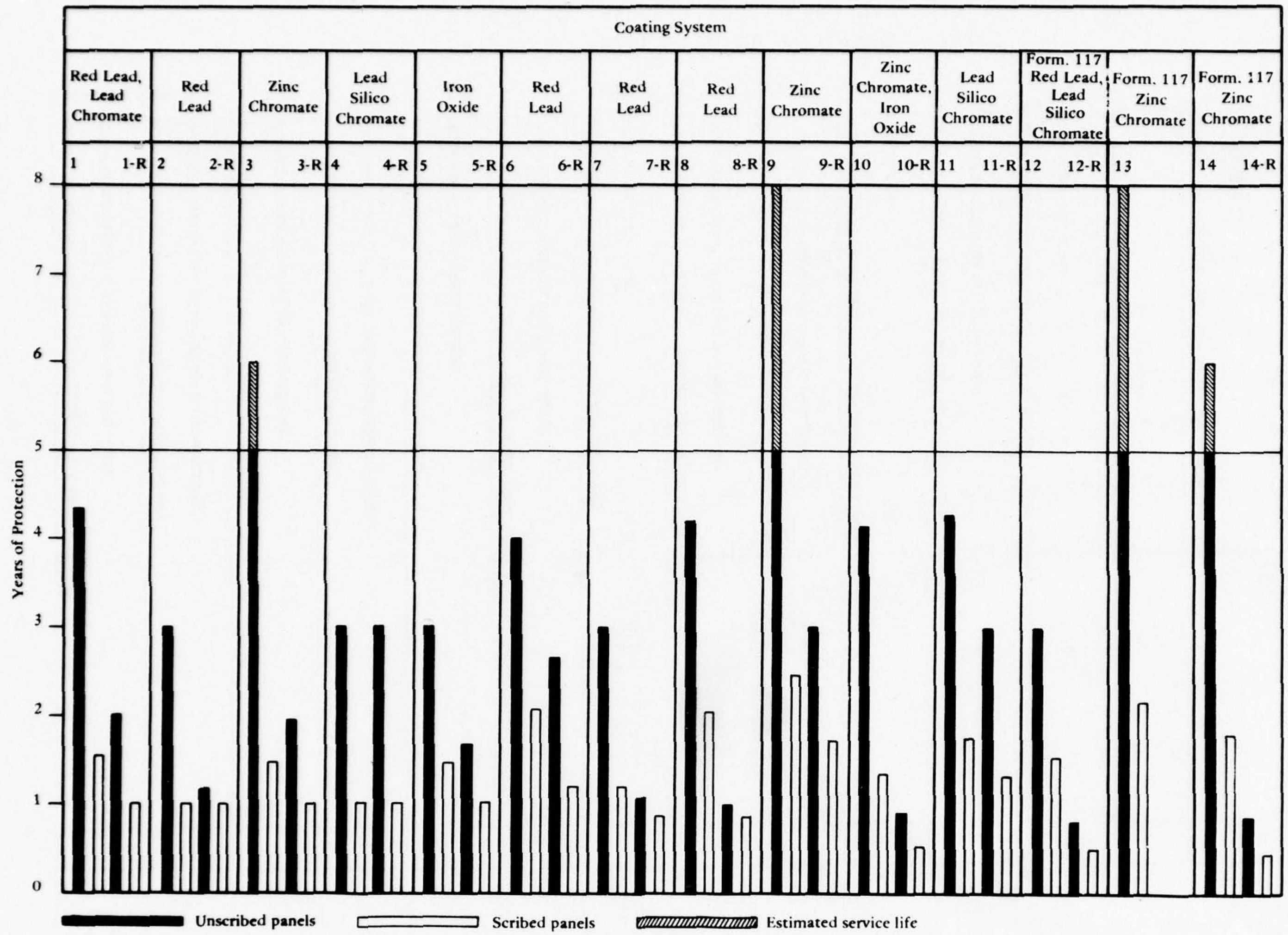

Figure 7. Relative performance of over-rust primers at Kwajalein after 5 yr of exposure.

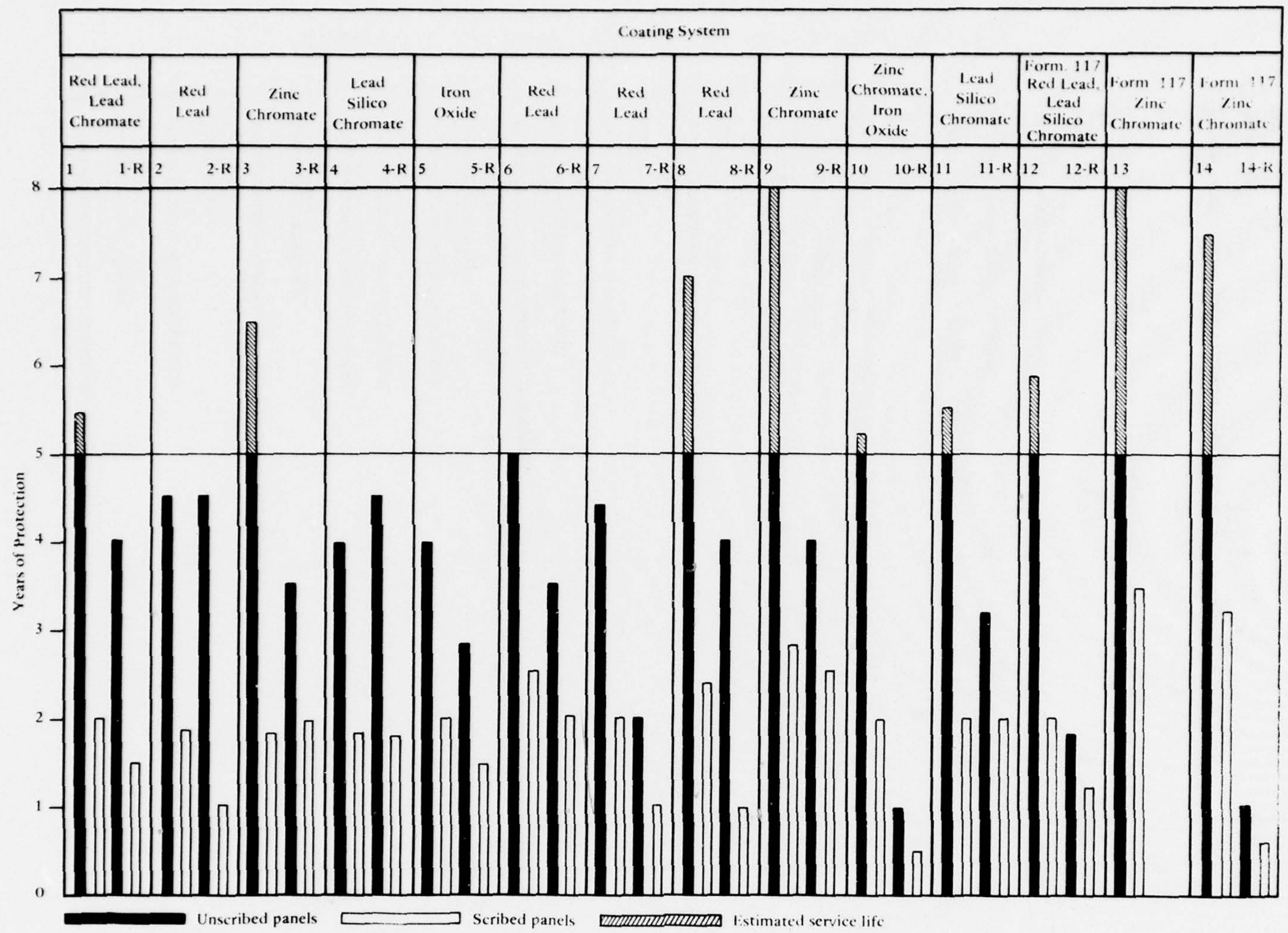

Figure 8. Relative performance of over-rust primers at Kaneohe after 5 yr of exposure.

Table 1. Years of Service Life[a] Provided by Over-Rust Primers at Three CEL Exposure Sites

System No.	Service Life (yr)													
	Kwajalein				Kaneohe				Port Hueneme				Total	Average
	Brush-off Sandblasted		Wire-brushed		Brush-off Sandblasted		Wire-brushed		Brush-off Sandblasted		Wire-brushed			
	U[b]	S[b]	U	S	U	S	U	S	U	S	U	S		
1	4.50	1.50	2.00	1.00	5.50	2.00	4.00	1.50	9.00	2.50	8.75	2.50	44.75	3.72
2	3.00	1.00	1.25	1.00	4.50	1.75	4.50	1.00	8.00	2.25	8.25	3.00	39.50	3.29
3	6.00	1.50	2.00	1.00	6.50	1.75	3.50	2.00	9.00	2.75	9.25	2.75	48.00	4.00
4	3.00	1.00	3.00	1.00	4.00	1.75	4.50	1.75	8.00	3.50	8.50	2.75	42.75	3.56
5	3.00	1.50	1.75	1.00	4.00	2.00	2.75	1.50	8.50	2.50	7.75	2.50	38.75	3.23
6	4.00	2.25	2.75	1.25	5.00	2.50	2.50	2.00	8.00	2.75	8.00	2.50	44.50	3.71
7	3.00	1.25	1.00	0.75	4.50	2.00	2.00	1.00	7.50	2.75	7.25	2.75	35.75	2.98
8	4.25	2.00	1.00	0.75	7.00	2.50	4.00	1.00	11.00	2.75	9.50	2.50	41.25	3.43
9	8.00	2.50	3.00	1.75	8.75	2.75	4.00	2.50	11.00	4.50	10.00	3.50	62.25	5.18
10	4.25	1.25	0.75	0.50	5.25	2.00	1.00	0.50	9.50	2.75	7.00	1.50	36.25	3.02
11	4.50	1.75	3.00	1.50	5.50	2.00	3.25	2.00	8.50	2.50	9.00	2.50	46.00	3.83
12	3.00	1.50	0.75	0.50	5.75	2.00	1.75	1.25	8.00	2.50	6.50	2.50	36.00	3.00
13[c]	8.00	2.25	-	-	8.50	3.50	-	-	11.00	2.75	-	-	36.00	6.00
14	6.00	1.75	0.75	0.50	7.50	3.25	1.00	0.50	9.00	3.50	3.00	2.75	39.50	3.29
Total	64.50	23.00	23.00	12.50	82.25	31.75	43.75	18.50	126.00	40.25	102.75	34.00		
Average	4.60	1.64	1.77	0.96	5.87	2.27	3.37	1.42	9.00	2.88	7.90	2.61		

[a] Service lives over 5 yr were estimated.

[b] U = unscribed panel, S = scribed panel.

[c] Sandblasted control standard.

Scribed Panels. At Kwajalein, Systems 6, 8, 9, and 13* failed during the third year of exposure, while others failed before or during the second year of exposure. Average service life was 1.6 yr at Kwajalein. At Kaneohe, average service life was 2.3 yr. Systems 13 and 14 lasted about 1-1/2 yr longer at Kaneohe than at Kwajalein and failed during the fourth year. Only three coating systems on brush-off blasted panels (Systems 4, 9, and 14) were still providing protection to scribed panels at Port Hueneme at the end of 3 yr. Average service life for all scribed panels was 2.9 yr at Port Hueneme.

Systems Applied Over Wire-Brushed Panels

Unscribed Panels. None of the coating systems, including the control standards, provided satisfactory protection to wire-brushed rusted panels beyond 3 yr at Kwajalein. However, Systems 4 (alkyd lead silico chromate), 9 (alkyd zinc chromate) and 11 (phenolic lead silico chromate) provided satisfactory protection up to 3 yr before failing at Kwajalein. System 6 (alkyd red lead) failed near the end of the third year of exposure. Also, Systems 1 and 3 provided protection up to 2 yr of exposure, but the other remaining coatings failed earlier. Average service life was 1.8 yr at Kwajalein. System 14 failed in less than 12 mo of exposure. Early coating failure of System 14 compared to System 3 indicates that wash primer (MIL-P-15328) did not provide added protection when used over a wire-brushed rusty surface. None of the 13 coating systems provided satisfactory protection beyond 4 yr of exposure at Kaneohe, except System 2 (phenolic red lead) and System 4 (alkyd lead silico chromate), which still provided protection until failing during the fifth year. Systems 10 and 14 failed during the first year of exposure at Kaneohe. Average service life was 3.4 yr at Kaneohe. Twelve of the 13 coating systems at Port Hueneme were providing satisfactory protection at the end of 5 yr of exposure. System 14 failed during the fourth year of exposure at Port Hueneme. Projected average service life was 7.9 yr.

Scribed Panels. At Kwajalein, only Systems 6, 9, and 11 provided protection beyond 1 yr of exposure. Average service life was 1 yr as given in Table 1. Except for System 9, all other coating systems failed to provide protection beyond 2 yr of exposure at Kaneohe and beyond 3 yr of exposure at Port Hueneme. Average service lives were 1.4 and 2.6 yr, respectively. System 9 failed near the end of the second year of exposure at Kwajalein, and during the third and fourth year at Kaneohe and Port Hueneme, respectively.

Correlation and Regression Analysis

As previously stated, both Kwajalein and Kaneohe are located in tropical environments. The performance of individual coating systems, given in Appendix C, shows that the deterioration of a coating and the

*Sandblasted control standard.

time to its failure are accelerated when exposed at these sites when compared to exposure at Port Hueneme. This acceleration was more pronounced at Kwajalein than Kaneohe. Thus, exposure at the corrosive environment of Kwajalein should help to eliminate inferior coating systems and to predict the relative performance of superior coating systems more quickly than is possible at the other two exposure sites.

Figures 9 and 10 illustrate the relative service lives of the 13 unscribed over-rust primers applied over rusted steel panels which have received brush-off sandblasted or wire-brushed surface preparation, respectively. These figures also show the System 13 control after exposure for 5 yr at the three CEL test sites. Each point represents the years of exposure until the coating fails or is expected to fail. For those coating systems which did not fail at the end of 5 yr of exposure, the best estimates (nearest quarter of a year) of expected service life were given, based on condition of the coating systems at the time of the final inspection after the 5 yr of exposure.

Figures 9 and 10 were constructed by joining the points representing total service life of unscribed panels at the respective exposure sites. These display clearly the general parallelism in system performance and the relative severity of exposure at the three sites. It is apparent from these figures that the service lives of coating systems exposed at Kwajalein are shorter than those exposed at Kaneohe and much shorter than those exposed at Port Hueneme.

Correlation between the service lives of unscribed, over-rust primer coating systems on brush-off sandblasted rusted steel panels at Kwajalein and of such panels at Kaneohe and Port Hueneme sites were statistically determined by computing correlation coefficient τ using the data from Table 1. Results are given in Table 2 together with the critical values at different levels of significance.

The calculated correlation coefficients τ for systems on unscribed brush-off blasted panels between the service lives of the coating systems at Kwajalein and Port Hueneme, and at Kwajalein and Kaneohe, and at Kaneohe and Port Hueneme, were 0.77, 0.92 and 0.83 (at 12 deg of freedom), respectively. The critical τ-values at the 99% and 99.9% level were 0.661 and 0.780, respectively. The τ-values obtained exceeded the critical values at the 99% or 99.9% level, which indicates that the correlation of the service lives among the three CEL exposure sites are statistically highly significant or very highly significant.

Correlation coefficients were calculated similarly for the systems on unscribed wire-brushed rusted steel panels exposed at the three CEL test sites. The results of the τ-values are also given in Table 2.

The calculated correlation coefficient τ between the service lives of these coating systems at Kwajalein and Port Hueneme, at Kwajalein and Kaneohe, and at Kaneohe and Port Hueneme were 0.61, 0.64, and 0.76, respectively (at 12 deg of freedom). The τ-values obtained exceeded the critical values at the 95% or 99% level, which indicates that the correlation among the service lives of these coating systems at the three CEL sites are statistically significant or highly significant.

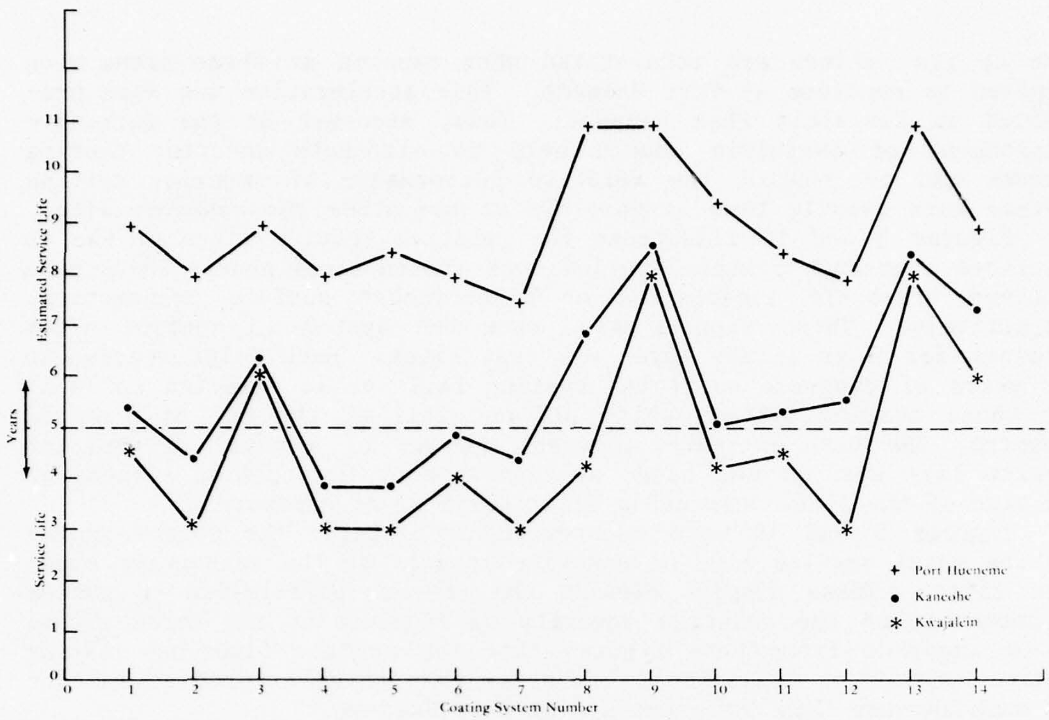

Figure 9. Service life of unscribed over-rust primer coating systems, applied over brush-off sandblasted panels and exposed at three CEL test sites. (System 13 is sandblasted control standard.)

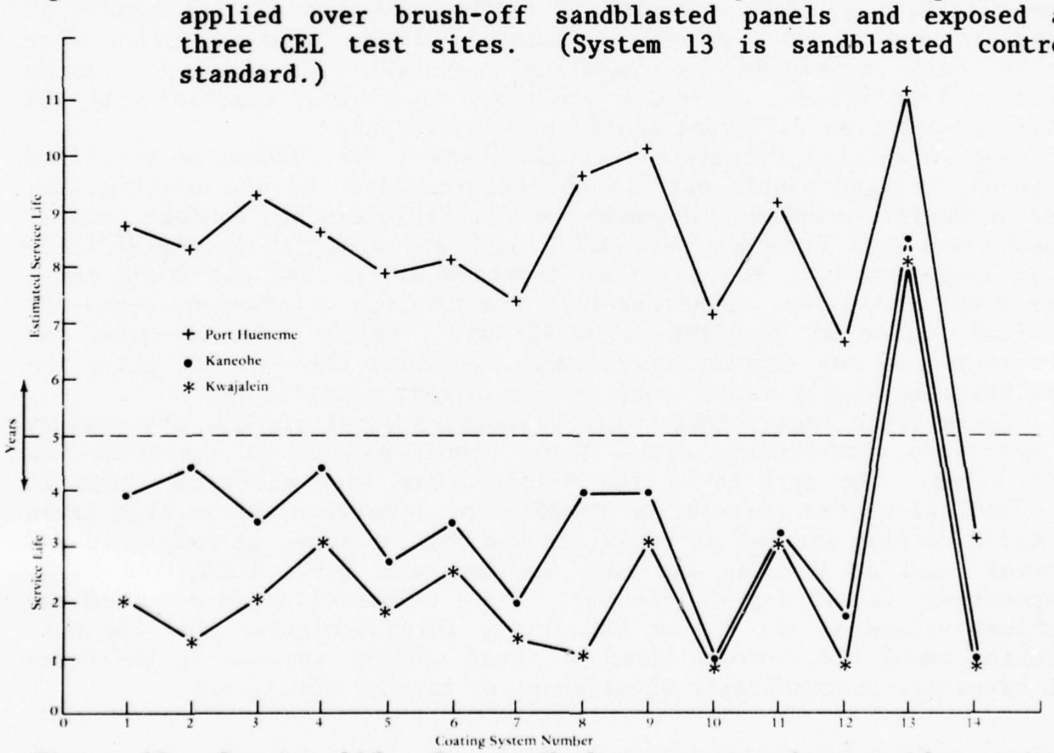

Figure 10. Service life of unscribed over-rust primer coating systems, applied over wire-brushed panels, at three CEL exposure sites. (System 13 is sandblasted control standard.)

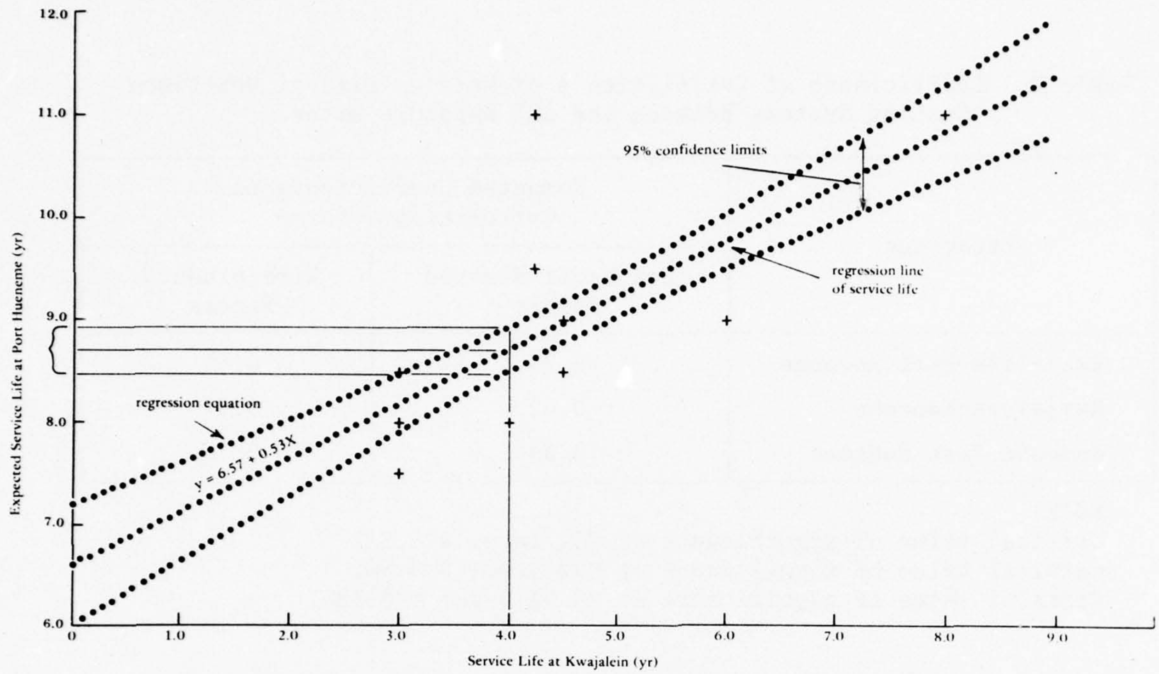

Figure 11. Estimation of Port Hueneme service life of over-rust primer coating system applied over brush-off sandblasted surface, based on Kwajalein service data.

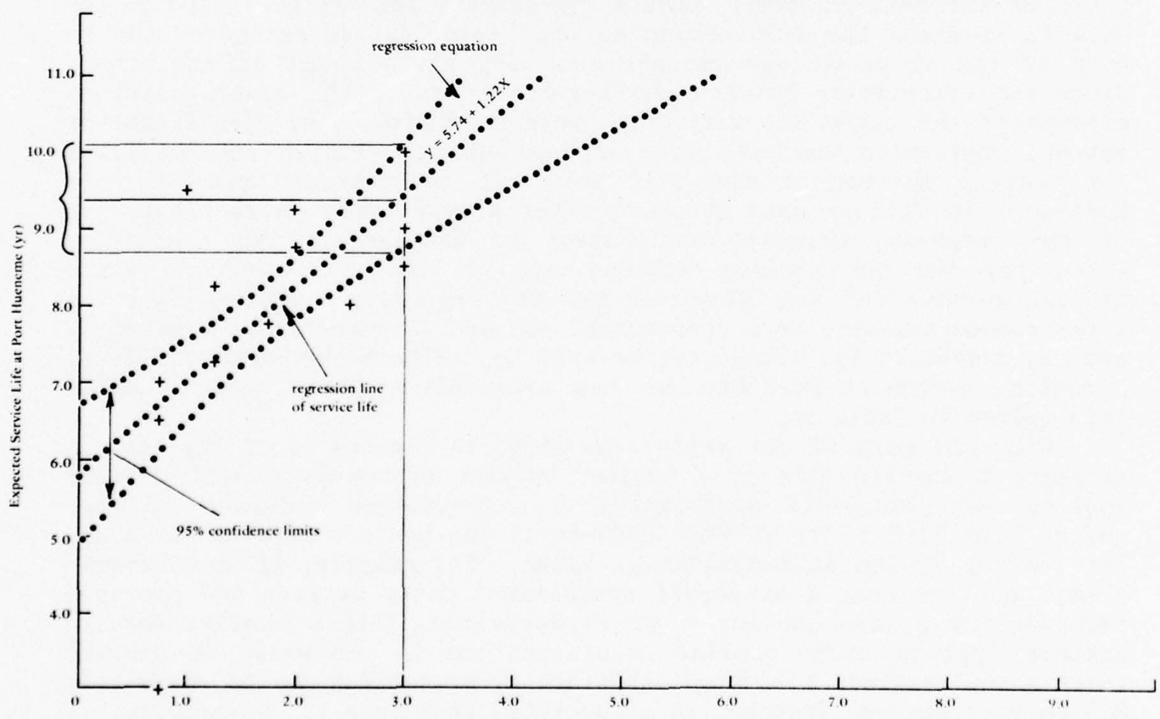

Figure 12. Estimation of Port Hueneme service life of over-rust primer coating system applied over wire-brushed rusted surface, based on Kwajalein service data.

Table 2. Coefficients of Correlation τ of Service Life of Unscribed Coating Systems Between the CEL Exposure Sites

Locations	Computed Coefficients of Correlation τ for--	
	Brush-off Blasted Panels	Wire-brushed Panels
Kwajalein–Port Hueneme	0.77	0.61
Kwajalein–Kaneohe	0.92	0.64
Kaneohe–Port Hueneme	0.83	0.76

NOTE:
Critical value of significance at 95% level = 0.532
Critical value of significance at 99% level = 0.661
Critical value of significance at 99.9% level = 0.780

Correlation coefficients are used to determine if the relationship between two variables is real. If the relationship is real (on the basis of the data at hand), then a regression line can be fitted to the data to condense the information so that quantitative estimates can be made of the value of one variable for any given value of the other. Since the correlation between the service lives of the coating systems exposed at the three CEL test sites were concluded to be significant or better, regression analyses make it possible to predict service lives for coating systems at the mild and less corrosive climate of Port Hueneme from failure data obtained after a relatively shorter exposure in the severely corrosive environment of Kwajalein. Two regression lines (one for the coating systems applied over the brush-off sand-blasted surface and the other for the coating systems applied over the wire-brushed surface) were constructed and are illustrated in Figures 11 and 12, respectively. These can be used to estimate the service life of a coating system at Port Hueneme from available exposure data of Kwajalein (given in Table 1).

With the help of the regression lines in Figures 11 or 12, one can estimate a service life of a similar coating system (over-rust primers applied over brush-off sandblasted or wire-brushed surfaces and top-coated with TT-E-489D) at Port Hueneme if the service life of the similar coating system in Kwajalein is known. For example, if an over-rust primer applied over a brush-off sandblasted rusty surface had provided satisfactory protection for 4 yr at Kwajalein, then a similar coating systems applied under similar conditions can be estimated to provide (within 95% confidence limits) satisfactory protection for approximately 8.5 to 9 yr at Port Hueneme, as illustrated in Figure 11. Similarly, if

an over-rust primer applied over a wire-brushed rusted surface had provided 3 yr of satisfactory protection at Kwajalein, then a similar coating system can be estimated to provide (within 95% confidence limits) satisfactory protection for approximately 8.75 to 10.25 yr at Port Hueneme, as illustrated in Figure 12. To be able to make a reliable prediction of service life of a coating system by the above approach, it is necessary that the coating systems be similar in type and applied under similar conditions as those exposed at the exposure sites. To further illustrate this point, Figures 11 and 12 have demonstrated that two different surface preparations - brush-off sandblasted or wire-brushed - have led to two different regression equations and two different regression lines, in spite of the coating systems being exactly the same and samples prepared and placed at the same time at the two exposure sites.

CONCLUSIONS

1. System 9, consisting of an over-rust primer (proprietary alkyd zinc chromate), gave comparable protection for 5 yr in a marine atmospheric environment to brush-off sandblasted rusted steel as that provided by the control standard, System 13, coated over a sandblasted surface.

2. System 9 gave the best protection to rusted steel compared to the other coating systems tested, and it gave better protection than that provided by System 14, whether the surface was prepared by brush-off sandblasting or by wire-brushing.

3. Except for System 9, over-rust primers are generally ineffective in protecting rusted metal surfaces in highly humid areas or in corrosive environments such as Kwajalein and Kaneohe. However, it can be effective at a much less corrosive environment such as in Port Hueneme, where it is estimated that superior over-rust primers can protect wire-brushed rusted areas for approximately 8 yr or more as long as the coated surfaces are protected from mechanical abrasion. Once the coating is damaged, however, the coated area will deteriorate very rapidly.

4. The wash primer (Formula 117) develops good adhesion to sandblasted steel and provides a sound base for top-coating. However, comparison of the protection provided by System 3 and System 14 (without and with Formula 117, respectively) indicated that the Formula 117 did not provide the expected protection when used over brush-off sandblasted and wire-brushed rusted steel surfaces.

5. It is possible to estimate anticipated durability of coating systems at one site from those at another by a regression analysis under controlled test conditions. To be able to make a satisfactory prediction for the performance of a new coating system in an environment similar to that at one of the three exposure sites, it must be similar in type to those already investigated at the sites, have similar surface preparation, and begin exposure at the same time of year and remain on exposure at Kwajalein until failure. Reliability of the prediction will increase if the service lives of the other test coatings exposed are known rather than using estimated values as presented in this report.

6. The overall result of this work supports the conclusion that the coating systems applied over a sandblasted steel surface perform better than the systems applied over a brush-off sandblasted rusty surface; and systems with brush-off sandblasted surfaces perform better than the systems applied over a wire-brushed rusty surface: the cleaner the surface, the better the performance.

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Mr. C. V. Brouillette (retired) initiated the project covered by this report and co-authored Reference 1, giving results after 3 yr of exposure. Support provided by Mr. A. Curry (retired) of CEL, who prepared the test specimens and helped prepare the tables in this report, is appreciated.

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Appendix A

PHYSICAL PROPERTIES AND COMPOSITION OF OVER-RUST PRIMERS

System[a] No.	Designation	Primer Name	Weight Per Gallon (lb)	Specific Gravity (g/ml)	Viscosity (Kreb Units)	Nonvolatile Solids (%)	Pigment (%)	Nonvolatile Vehicle (%)
1	TT-E-485E, Type II	Alkyd red lead/lead chromate		Meets specification				
2	TT-P-0086E	Red lead phenolic (tung oil)		Meets specification				
3	TT-P-645	Alkyd zinc chromate		Meets specification				
4	TT-P-615d	Lead silico chromate (oil alkyd)		Meets specification				
5	TT-C-530a	Iron oxide and fish oil base		Meets specification				
6	MIL-P-17545	Alkyd red lead		Meets specification				
7	proprietary	Red lead (fish oil)	10.9	–	81	73.33	44.43	28.90
8	proprietary	Alkyd red lead	16.8	–	85	80.05	65.49	14.56
9	proprietary	Alkyd zinc chromate	12.8	–	67	75.07	58.07	17.00
10	proprietary	Vinyl/alkyd zinc chromate-iron oxide	13.2	–	P2	50.32	–	–
11	proprietary	Phenolic lead silico chromate	12.1	–		74.88	49.69	25.19
12	proprietary	Alkyd (long oil)	15.65	1.878	89	83.55	66.14	17.41
13[b]	MIL-P-15328B	Polyvinyl butyral resin (Formula 117)		Meets specification				
	TT-P-645	Alkyd zinc chromate		Meets specification				
14	MIL-P-15328B	Polyvinyl butyral resin (Formula 117)		Meets specification				
	TT-P-645	Alkyd zinc chromate		Meets specification				

[a] All systems were top coated with alkyd enamel TT-E-489D, which meets specification.

[b] System 13 panels were the sandblasted control standards.

Appendix B

COATING SYSTEMS, THEIR SOURCES AND COMPONENTS

System No.	Primer Type[a]	Coating System		System Components	Use	No. of Coats	Thickness (mil)
		Sources of Primer	Specification No. or Trade Names				
1	Alkyd	Navy stock	TT-E-485E, Type II	Red lead/lead chromate	primer	1	2.0
			TT-E-489D, Amendment 1, Class A	Alkyd enamel	finish	3	4.0
							6.0
2	Phenolic	San Diego Coating Co. 2646 Main St San Diego, CA 92113	TT-P-0086E, Type 4	Red lead (tung oil)	primer	1	2.5
			TT-E-489D, Amendment 1, Class A	Alkyd enamel	finish	3	4.0
							6.5
3	Alkyd	San Diego Coating Co. 2646 Main St San Diego, CA 92113	TT-P-645	Alkyd zinc chromate	primer	1	2.5
			TT-E-489D, Amendment 1, Class A	Alkyd enamel	finish	3	4.0
							6.5
4	Oil-alkyd	San Diego Coating Co. 2646 Main St San Diego, CA 92113	TT-P-615D Type II	Lead silico chromate	primer	1	2.5
			TT-E-489D, Amendment 1, Class A	Alkyd enamel	finish	3	3.5
							6.0
5	Oil	San Diego Coating Co. 2646 Main St San Diego, CA 92113	TT-C-530A	Iron oxide (fish-oil)	primer	1	2.5
			TT-E-489D, Amendment 1, Class A	Alkyd enamel	finish	3	3.5
							6.0

continued

System No.	Primer Type[a]	Coating System: Sources of Primer	Coating System: Specification No. or Trade Names	System Components	Use	No. of Coats	Thickness (mil)
6	Alkyd	Navy stock	MIL-P-17545	Alkyd red lead	primer	1	3.25
			TT-E-489D, Amendment 1, Class A	Alkyd enamel	finish	3	3.50
							6.75
7	Oil-alkyd	Rust-Oleum Corp. 2425 Oakton St Evanston, IL 60204	Damp proof #769	Red lead (fish-oil)	primer	1	2.5
			TT-E-489D, Amendment 1, Class A	Alkyd enamel	finish	2	3.5
							6.0
8	Alkyd	Enjay Chemical Co. 8230 Stedman St Houston, TX 77029	Enjay #6273	Alkyd red lead	primer	1	2.5
			TT-E-489D, Amendment 1, Class A	Alkyd enamel	finish	2	3.5
							6.0
9	Alkyd	Enjay Chemical Co. 8230 Stedman St Houston, TX 77029	Enjay #6262	Alkyd zinc chromate	primer	1	2.5
			TT-E-489D, Amendment 1, Class A	Alkyd enamel	finish	2	3.5
							6.0
10	Vinyl-alkyd	PPG Industry Inc. No. 1 Gateway Center Pittsburgh, PA 15222	Multiprime	Zinc chromate-iron oxide	primer	1	2.25
			TT-E-489D, Amendment 1, Class A	Alkyd enamel	finish	2	3.00
							5.25

continued

System No.	Primer Type[a]	Coating System		System Components	Use	No. of Coats	Thickness (mil)
		Source of Primer	Specification No. or Trade Names				
11	Phenolic	Steelcote Mfg. Co. 3418 Grotiot St St Louis, MO 63103	Halts Rust 1-2-3	Phenolic lead silico chromate	primer	1	2.25
			TT-E-489D, Amendment 1, Class A	Alkyd enamel	finish	2	3.00
							5.25
12	Oil-alkyd	Patterson Sargent Div. of Textron Ind. P.O. Box 494 New Brunswick, NJ 08903	Vita Var #14142	Red lead, lead silico chromate alkyd	primer	1	2.35
			TT-E-489D, Amendment 1, Class A	Alkyd enamel	finish	2	3.5
							5.85
13	Polyvinyl butyral resin (wash)	San Diego Coating Co. 2646 Main St San Diego, CA 92113	MIL-P-15328	Polyvinyl butyral	wash primer	1	0.5
	Alkyd		TT-P-645	Zinc chromate alkyd	primer	1	3.25
			TT-E-489D, Amendment 1, Class A	Alkyd enamel	finish	2	3.50
							7.25
14	Polyvinyl butyral resin (wash)	San Diego Coating Co. 2646 Main St San Diego, CA 92113	MIL-P-15328	Polyvinyl butyral	wash primer	1	0.5
	Alkyd		TT-P-645	Zinc chromate alkyd	primer	1	2.5
			TT-E-489D, Amendment 1, Class A	Alkyd enamel	finish	2	3.25
							6.25

[a]Primer and source of primers only; Navy stock item TT-E-489D was used for all finish coats.

Appendix C

RATING DATA FOR OVER-RUST PRIMERS

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels[a]		
			Protection	Chalking	Blistering	Undercutting Edges	Rusting (Type)		Protection	Blistering	Undercutting
							I	II			
1	Kwajalein	1	10	6	10	10	10	10	8–[b]	4/D	9
		2	9	6	10	10	4(E)[c]	6(E)	5	2/D	8
		3	8(E)	4	4/D(E)	6(E)	2(E)	2(E)			
		4	8–	4	4/D(E)	4(E)	1(E)	2(E)			
		5	7	4	4/D(E)	4(E)	0(E)	2(E)			
	Kaneohe	1	10	6	10	10	10	10	8	2/D	8
		2	9	6	9(E)	10	9	9(E)	7	2/D	4
		3	9	6	8(E)	10	9	9(E)			
		4	8	4	7/M(E)	9	4(E)	7(E)			
		5	8	4		7(E)	2(E)	5(E)			
	Port Hueneme	1	10	8	8/F	10	10	10	9	4/MD	10
		2	10	6	8/F	10	9(E)	10	8–	4/MD	10
		3	9+	6	4/F	10	8(E)	10	7	4/D	10
		4	9	6	4/F	10	7	6			
		5	9	6	4/M(E)	10	7	6			
1-R	Kwajalein	1	8	4		10	10	6(E)	7	4/D	10
		2	7	6			0(E)	0(E)			
		3	—	—							
		4									
		5									
	Kaneohe	1	8+	6	10	10	9(E)	8(E)	8–	2/D	8
		2	8	4	8	8(E)	6(E)	8(E)	7	2/D	8(E)
		3	8–	4	4/MD(E)	7(E)	4(E)	5(E)			
		4	7	4	2/MD(E)	5(E)	3(E)	2(E)			
		5									
	Port Hueneme	1	10	8	8/F	10	10	10	9	4/MD	10
		2	10	8	8/F	10	10	10	8–	4/MD	10
		3	9	6	6/M(E)	10	8(E)	9(E)	7	4/D	10
		4	9–	6	6/M(E)	9(E)	9(E)	9(E)			
		5	9–	6	6/M(E)	9(E)	9(E)	9(E)			

continued

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels[a]		
			Protection	Chalking	Blistering	Undercutting Edges	Rusting (Type) I	Rusting (Type) II	Protection	Blistering	Undercutting
2	Kwajalein	1	9	8	10	10	9(E)	9(E)	7	6/D	10
		2	8	8	10	10	2(E)	6(E)			
		3	7[d]	4	4/D(E)	4(E)	0(E)	2(E)			
		4									
		5									
	Kaneohe	1	10	6	10	10	10	9(E)	8	2/D	6
		2	9	4	10	10	8(E)	8(E)	7	2/D	6
		3	8	4	4/F(E)	9(E)	7(E)	8(E)			
		4	8	4	4/F(E)	8	6(E)	8(E)			
		5	7	4	4/F(E)	8(E)	6(E)	6(E)			
	Port Hueneme	1	10	10	10	10	10	10	9	4/MD	10
		2	9+	10	10	10	8(E)	10	8–	4/D	10
		3	9	6	8/F(E)	10	6(E)	8(E)	6[e]	4/D	10
		4	8+	6	8/F(E)	8(E)	5(E)	7(E)			
		5	8+	6	8/M	8(E)	4(E)	6(E)			
2-R	Kwajalein	1	8–	8	6(E)	10	6(E)	6(E)	6	4/D	8
		2	7	4	4/D(E)	6(E)	3(E)	4(E)			
		3									
		4									
		5									
	Kaneohe	1	9	8	10	10	8(E)	10	7	0/D	6
		2	8	6	10	10	6(E)	6(E)			
		3	8	4	4/F(E)	10	6(E)	6(E)			
		4	8–	4	4(E)	10	5(E)	5(E)			
		5	7	4	–	6(E)	2(E)	4(E)			
	Port Hueneme	1	10	8	6/F	10	10	10	9	6/MD	10
		2	10	8	6/F	10	10	10	9–	6/D	10
		3	9	6	6-8/M	10	8(E)	9(E)	7[e]		
		4	8+	6	6-8/M	10	7(E)	9(E)			
		5	8	6	6/M	10	6(E)	8(E)			

continued

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels[a]		
			Protection	Chalking	Blistering	Undercutting Edges	Rusting (Type)		Protection	Blistering	Undercutting
							I	II			
		1	10	8	10	10	10	10	8	4/MD	10
		2	9	6	10	10	8(E)	10	7–	2/D	8
	Kwajalein	3	8+	4	6/M(E)	10	4(E)	6(E)			
		4	8	4	6/M(E)	8(E)	3(E)	5(E)			
		5	8–	4	6/M(E)	7(E)	3(E)	5(E)			
		1	10	6	10	10	10	10	8	2/D	8
		2	10	6	10	10	10	10	7	2/D	6
3	Kaneohe	3	9	6	8/M(E)	10	9(E)	10			
		4	9–	4	8/M(E)	9(E)	8(E)	9			
		5	8	4	8/M(E)	9(E)	7(E)	8(E)			
		1	10	8	10	10	10	10	9	6/M	10
		2	10	8	10	10	10	10	8	6/MD	10
	Port Hueneme	3	9+	6	8/F(E)	10	10	10	7^e		
		4	9	6	8/F(E)	10					
		5	9	6	8/F(E)	9(E)					
		1	9	8	10	10	9	9(E)	7	4/D	8
		2	7	6	6/MD	8(E)	2(E)	8			
	Kawajalein	3									
		4									
		5									
		1	9–	6	10	10	10	8^e	8	4/MD	8
		2	8	6	6^f	10	6(E)	8(E)	7	2/MD	6
3-R	Kaneohe	3	8	4	4/MD(E)	9(E)	6(E)	6(E)			
		4	7	4	4/MD(E)	7(E)	4(E)	5(E)			
		5									
		1	10	8	6/F	10	10	10	9–	6/MD	10
		2	10	8	6/F	10	10	10	8	6/MD	10
	Port Hueneme	3	9+	6	6-8/M	10	10	10	7^e	2/D	10
		4	9	6	6/M	10	9(E)	10			
		5	9	6	6/M	10	9(E)	9(E)			

continued

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels[a]		
			Protection	Chalking	Blistering	Undercutting Edges	Rusting (Type) I	Rusting (Type) II	Protection	Blistering	Undercutting
4	Kwajalein	1	9	6	4/F(E)	10	9(E)	9(E)	7	2/D	8
		2	8	6	4/M(E)	8(E)	4(E)	6(E)			
		3	7[d]	4	2/MD(E)	4(E)	2(E)	4(E)			
		4									
		5									
	Kaneohe	1	10	6	10	10	10	10	8	4/D	10
		2	9–	6	10	10	8(E)	8(E)	7	2/D	8
		3	8	4	2/F(E)	8(E)	8(E)	8(E)			
		4	7	6	2/M(E)	7(E)	6(E)	7(E)			
		5									
	Port Hueneme	1	10	8	10	10	10	10	9	6/M	10
		2	10	8	10	10	9(E)	10	9	4/M	10
		3	9	4	10	10	8(E)	9(E)	8–	2/MD	10
		4	9–	6	8/F(E)	9(E)	7(E)	8(E)	7	2/MD	4/S
		5	8+	6	8/M(E)	8(E)	6(E)	7(E)			
4-R	Kwajalein	1	9	6	10	10	9(E)	9(E)	7	4/D	9
		2	8	6	6/MD	6(E)	0(E)	4(E)			
		3	7[d]	4	2/D(E)	2(E)	0(E)	2(E)			
		4									
		5									
	Kaneohe	1	10[g]	6	10	10	10	10	8	4/MD	8
		2	9–	4	10	10	8(E)	8(E)	7	2/D	6
		3	8	4	2/F(E)	8(E)	8(E)	8(E)			
		4	8–	4	2/M(E)	7(E)	6(E)	7(E)			
		5	7	4	2/M(E)	6(E)	3(E)	5(E)			
	Port Hueneme	1	10	8	6/M	10	10	10	9	4/M	10
		2	10	8	6/M	10	9(E)	10	8	4/MD	10
		3	9+	6	6/MD	10	8(E)	9(E)	7[e]	4/M	10
		4	9	6	6/MD	10	8(E)	9(E)			
		5	9–	6	6/MD	9(E)	7(E)	8(E)			

continued

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels[a]		
			Protection	Chalking	Blistering	Undercutting Edges	Rusting (Type) I	Rusting (Type) II	Protection	Blistering	Undercutting
5	Kwajalein	1	9	6	10	10	9(E)	9(E)	8	4/D	6
		2	8	6	6/MD(E)	8(E)	4(E)	6(E)	7	2/D	
		3	7[d]	6	2/MD(E)	5(E)	4(E)	5(E)			
		4									
		5									
	Kaneohe	1	10	6	10	10	10	10	8	2/D	8
		2	9	4	10	10	8(E)	8(E)	7	2/D	6
		3	8	4	2/F(E)	10	8(E)	8(E)			
		4	7	4	2/M(E)	10	7(E)	7(E)			
		5			2/M(E)	7(E)	2(E)	5(E)			
	Port Hueneme	1	10	8	8/F	10	10	10	9	6/D	10
		2	10	8	8/F	10	8(E)	10	8–	4/D	10
		3	9	6	8/M	10	7(E)	9(E)	7[d]	4/D	10
		4	9–	6	8/M(E)	9(E)	6(E)	8(E)			
		5	8+	6	8/M(E)	8(E)	6(E)	8(E)			
5-R	Kwajalein	1	8	6	6(E)	10	8(E)	6(E)	7–	2/D	10
		2	7	4	6/MD	6(E)	0(E)	6			
		3									
		4									
		5									
	Kaneohe	1	9	6	10	10	9(E)	8(E)	8	2/D	6
		2	8–	4	6	10	6(E)	8(E)	7	2/D	6
		3	7	4	2/MD(E)	6(E)	2(E)	2(E)			
		4									
		5									
	Port Hueneme	1	10	8	8/M	10	10	10	9	6/MD	10
		2	9	8	8/M	10	9(E)	10	8–	6/D	10
		3	9–	6	8/M	10	7(E)	8(E)	7[d]	4/D	10
		4	9–	6	8/M(E)	9(E)	6(E)	7(E)			
		5	8+	6	8/M(E)	8(E)	5(E)	6(E)			

continued

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels[a]		
			Protection	Chalking	Blistering	Undercutting Edges	Rusting (Type) I	Rusting (Type) II	Protection	Blistering	Undercutting
6	Kwajalein	1	10	6	10	10	9(E)	10	8	4/D	10
		2	9	6	6/M	10	5(E)	8[f]	7+	2/D	8
		3	8	4	6/M	8(E)	2(E)	6(E)			
		4	8	6	6/M	6(E)	1(E)	4(E)			
		5	7	4	10	10	1(E)	3(E)			
	Kaneohe	1	9	6	10	10	8(E)	10	8	2/D	8
		2	8	4	10	10	6(E)	8(E)	7	2/D	6
		3	8	4	4/F(E)	10	6(E)	6(E)			
		4	8–	4	2/M(E)	10	4(E)	4(E)			
		5	7	4	2/M(E)	5(E)	1(E)	3(E)			
	Port Hueneme	1	10	8	8/F	10	10	10	9	6/D	10
		2	9+	8	8/F	10	9(E)	10	8	4/D	10
		3	9	6	8/M	10	6(E)	8(E)	7[e]	4/D	10
		4	9–	6	8/M	9(E)	5(E)	7(E)			
		5	8+	6	8/M	8(E)	4(E)	6(E)			
6-R	Kwajalein	1	9	6	6(E)	10	9(E)	6(E)	7	4/D	10
		2	7	4	6(M)	6(E)	0(E)	2(E)			
		3									
		4									
		5									
	Kaneohe	1	9	6	10	10	8(E)	8(E)	8–	0/D	6
		2	8	4	6/F	10	6(E)	8(E)	7	0/D	6
		3	8(E)	4	4/F(E)	8(E)	6(E)	6(E)			
		4	7	4	4/F(E)	7(E)	4(E)	5(E)			
		5		4	4/F(E)	6(E)	1(E)	2(E)			
	Port Hueneme	1	10	8	8/F	10	10	10	9	4/D	10
		2	10	8	8/F	10	10	10	8–	4/D	10
		3	9	6	8/M	10	7(E)	8(E)	7–[e]	4/D	10
		4	9–	6	8/M(E)	8(E)	5(E)	7(E)			
		5	8+	6	8/M(E)	7(E)	5(E)	7(E)			

continued

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels[a]		
			Protection	Chalking	Blistering	Undercutting Edges	Rusting (Type) I	Rusting (Type) II	Protection	Blistering	Undercutting
7	Kwajalein	1	9	6	10	10	8(E)	10	7	6/MD	10
		2	8	6	8/M	10	4(E)	5(E)			
		3	7	4	6/F	6(E)	4(E)	4(E)			
		4									
		5									
	Kaneohe	1	10	6	10	10	10	10	8	2/D	8
		2	8+	4	8/F	10	8	8(E)	7	2/D	8
		3	8	4	6/MD(E)	10	8(E)	8(E)			
		4	8–	4	4/MD(E)	8	7(E)	7(E)			
		5	7	4	4/MD(E)	7(E)	1(E)	3(E)			
	Port Hueneme	1	10	8	8/F	10	10	10	9	6/M	10
		2	10–	8	8/F	10	9(E)	10	8	6/M	10
		3	9	6	8/M(E)	10	8(E)	9(E)	7[e]	6/MD	10
		4	8+	6	8/M(E)	9(E)	8(E)	9(E)			
		5	8	6	8/M(E)	9(E)	7(E)	8(E)			
7-R	Kwajalein	1	7[b]	6	6/MD	10	10	6	6[b]	4/D	8
		2									
		3									
		4									
		5									
	Kaneohe	1	8	6	10	10	10	10	7	0/D	4
		2	7	6	6/M	10	4	4(E)			
		3									
		4									
		5									
	Port Hueneme	1	10	8	8/F	10	10	10	9	8/F	10
		2	10–	8	8/F	10	9(E)	10	8	8/F	10
		3	9–	6	8/M(E)	10	8(E)	9(E)	7	8/M	10
		4	8	6	8/M(E)	9(E)	5(E)	7(E)			
		5	8–	6	6/M(E)	7(E)	4(E)	7(E)			

continued

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels[a]		
			Protection	Chalking	Blistering	Undercutting Edges	Rusting (Type) I	Rusting (Type) II	Protection	Blistering	Undercutting
8	Kwajalein	1	10	6	10	10	10	9	8	6/D	10
		2	9	6	8/F	10	6(E)	8(E)	7+	2/D	6
		3	8	4	2/M	8(E)	4(E)	6(E)			
		4	8–	6	2/M	8(E)	2(E)	5(E)			
		5	7	6	2/D	5(E)	2(E)	4(E)			
	Kaneohe	1	10	6	10	10	10	10	8	6/D	8
		2	9	4	10	10	10	9(E)	7	4/D	6
		3	8+	4	8/F(E)	10	8(E)	8(E)			
		4	8+	4	6/F(E)	9(E)	8(E)	8(E)			
		5	8	4	6/F(E)	9(E)	7(E)	8(E)			
	Port Hueneme	1	10	8	10	10	10	10	9	6/MD	10
		2	10	8	10	10	10	10	8	6/D	10
		3	10	8	10	10	10	10	7[e]	4/M	10
		4	10	8	10	10	9(E)	10			
		5	10–	8	10	10	9(E)	10			
8-R	Kwajalein	1	8–	6	4/D	10	10	8/L[i]	7	4/D	10
		2	7								
		3									
		4									
		5									
	Kaneohe	1	9–	6	10	10	10	10	7	0/D	4
		2	8	4	10	10	8	8(E)			
		3	8	4	4/F(E)	10	8(E)	8(E)			
		4	8–	4	4/M(E)	8(E)	6(E)	7(E)			
		5	7	4	4/M(E)	6(E)	3(E)	5(E)			
	Port Hueneme	1	10	8	8/F	10	10	10	9	4/D	10
		2	10	8	8/F	10	10	10	8–	4/D	10
		3	9+	8	8/F	10	9(E)	10	7	2/D	10
		4	9+	6	8/F	10	9(E)	10			
		5	9	6	8/F	10	9(E)	9(E)			

continued

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels[a]		
			Protection	Chalking	Blistering	Undercutting Edges	Rusting (Type)		Protection	Blistering	Undercutting
							I	I			
9	Kwajalein	1	10	8	10	10	10	10	8	4/D	10
		2	9	6	8/MD	10	8(E)	9(E)	8–	2/D	8
		3	8+	4	4/M(E)	9(E)	8(E)	9(E)	4		
		4	8	4	4/M(E)	8(E)	8(E)	9(E)			
		5	8	4	4/M(E)	8(E)	8(E)	8(E)			
	Kaneohe	1	10[j]	6	10	10	10	10	8	2/D	8
		2	9+	6	8/F	10	10	10	8–	2/D	6
		3	9+	4	8/F(E)	10	10	9(E)	5		
		4	9	4	6/F(E)	9(E)	8(E)	9(E)			
		5	8+	4	6/M(E)	9(E)	8(E)	8(E)			
	Port Hueneme	1	10	8	10	10	10	10	9	6/F	10
		2	10	8	10	10	10	10	8+	2/M	10
		3	10–	6	10	10	10	10	8	2/MD	10
		4	10–	6	10	10	10	10	8–	2/MD	6
		5	10–	6	10	10	10	10	7		
9-R	Kwajalein	1	9–	8	6/MD	10	10	4/M	8–	6/D	10
		2	8+	6					6		
		3	8–	4							
		4	7	4							
		5									
	Kaneohe	1	9–	6	6/MD	10	6	6	8–	0/D	8
		2	8–	4					7–		
		3	8–	4							
		4	8–	4							
		5	7								
	Port Hueneme	1	10	8	10	10	10	10	9	6/D	10
		2	10	8	10	10	10	10	8	6/D	10
		3	10	8	10	10	9(E)	10	8–	4/D	10
		4	10	8	10	10	9(E)	10	7[e]	4/D	6
		5	10–	8	10	10	9(E)	10			

continued

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels[a]		
			Protection	Chalking	Blistering	Undercutting Edges	Rusting (Type) I	Rusting (Type) II	Protection	Blistering	Undercutting
10	Kwajalein	1	10	8	10	10	10	10	8–	4/D	10
		2	9	6	8/MD	10	8(E)	9(E)	4	2/D	8
		3	8	4	4/M(E)	9(E)	8(E)	9(E)			
		4	8–	4	4/M(E)	8(E)	4(E)	5(E)			
		5	6	4	4/M(E)	5(E)	3(E)	4(E)			
	Kaneohe	1	10[k]	6	10	10	10	10	8	2/D	8
		2	9	6	8/F	10	10	10	7	2/D	6
		3	8+	4	8/F(E)	10	10	9(E)			
		4	8–	4	6/F(E)	9(E)	8(E)	9(E)			
		5	7+	4	6/F(E)	9(E)	8(E)	9(E)			
	Port Hueneme	1	10	8	10	10	10	10	9	6/MD	10
		2	10	8	10	10	10	10	8	4/M	10
		3	10–	6	8/F(E)	10	9(E)	10	7	4/MD	10
		4	10–	6	8/F(E)	10	9(E)	10			
		5	10–	6	8/F(E)	10	9(E)	9(E)			
10-R	Kwajalein	1	6	6	6/MD	10	10	4/M	4	6/D	10
		2									
		3									
		4									
		5									
	Kaneohe	1	7	4	6/MD	10	6	6	5	0/D	8
		2									
		3									
		4									
		5									
	Port Hueneme	1	9	8	6/MD	10	10	10	8–	4/D	10
		2	9–	8	6/MD	10	9	8	7[e]	4/D	10
		3	8	6	6/D	10	8	7			
		4	8	6	6/D	9(E)	4(E)	5(E)			
		5	8–	6	6/D	7(E)	3(E)	4(E)			

continued

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels[a]		
			Protection	Chalking	Blistering	Undercutting Edges	Rusting (Type)		Protection	Blistering	Undercutting
							I	II			
11	Kwajalein	1	10	6	10	10	10	10	8	4/D	10
		2	9	6	8/M	10	8(E)	8(E)	7–	2/D	10
		3	8–	4	4/M	8(E)	4(E)	6(E)			
		4	8–	4	4/M	6(E)	2(E)	4(E)			
		5	7	4	4/M	5(E)	1(E)	2(E)			
	Kaneohe	1	10	6	10	10	10	10	8	4/D[l]	8
		2	9	4	8/F(E)	10	8(E)	9(E)	8–	2/D	8
		3	8+	4	8/M(E)	10	6(E)	8(E)	6		
		4	8	4	6/M(E)	9(E)	6(E)	8(E)			
		5	8–	4	6/M(E)	8(E)	4(E)	6(E)			
	Port Hueneme	1	10	8	8/F	10	10	10	9	6/MD	10
		2	10	6	8/F	10	9(E)	10	8–	6/D	10
		3	9+	8	8/F	10	8(E)	9(E)	7[e]	4/D	10
		4	9	8	8/F	9(E)	7(E)	9(E)			
		5	9–	8	8/F	9(E)	7(E)	8(E)			
11-R	Kwajalein	1	9	8	10	10	10	10	8–	4/D	9
		2	8–	6	6/MD	10	6(E)	6	5		
		3	7	4	6/D	6(E)	6(E)	4(E)[m]			
		4									
		5									
	Kaneohe	1	9	6	10	10	10	8(E)	8	2/D	8
		2	8	4	10	10	10	6(E)	7	2/D	6
		3	—	—	—	—	—	—	—	—	
		4									
		5									
	Port Hueneme	1	9	8	8/MD	10	10	10	9–	6/MD	10
		2	9	8	8/MD	10	10	10	8	4/MD	10
		3	9	6	8/MD[n]	10	9(E)	10	7	4/D	10
		4	9–	6	8/MD	10	9(E)	9(E)			
		5	9–	6	6-8/M	9(E)	9(E)	9(E)			

continued

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels[a]		
			Protection	Chalking	Blistering	Undercutting Edges	Rusting (Type) I	Rusting (Type) II	Protection	Blistering	Undercutting
12	Kwajalein	1	9	8	10	10	10	10	8–	2/D	10
		2	8–	6	6/MD	8(E)	4(E)	6(E)	5	2/D	8
		3	7[d]	4	6/D	6(E)	2(E)	2(E)			
		4									
		5									
	Kaneohe	1	9[p]	6	10	10	10	10	8	6/D	8
		2	8	4	8(E)	10	8(E)	8(E)	7	2/D	6
		3	8–[p]	4	6/D(E)	6(E)	6(E)	6(E)			
		4	8–	4	4/D(E)	6(E)	5(E)	5(E)			
		5	8–	4	4/D(E)	5(E)	2(E)	4(E)			
	Port Hueneme	1	9	8	8/MD	10	10	10	9	0/D	10
		2	9	8	8/MD	10	10	10	8–	0/D	10
		3	9–	6	8/MD	10	7(E)	8(E)	7[e]	0/D	10
		4	9–	6	8/MD	9(E)	6(E)	8(E)			
		5	8+	6	8/MD	8(E)	6(E)	7(E)			
12-R	Kwajalein	1	7	6	6/D	10	10	6/M	5	4/D	10
		2									
		3									
		4									
		5									
	Kaneohe	1	8	6	10	10	5(E)	8(E)	7[e]	2/D	6
		2	7	4	6/MD(E)	8(E)	4(E)	6(E)			
		3									
		4									
		5									
	Port Hueneme	1	9–	8	6/D	10	10	10	9–	4/D	10
		2	9–	8	6/D	10	9(E)	8(E)	8	4/D	10
		3	8	6	4-6/D	10	2(E)	6(E)	7[e]	2/D	10
		4	8–	6	4-6/D	6(E)	2(E)	4(E)			
		5	8–	6	4-6/D	5(E)	1(E)	3(E)			

continued

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels[a]		
			Protection	Chalking	Blistering	Undercutting Edges	Rusting (Type) I	Rusting (Type) II	Protection	Blistering	Undercutting
13	Kwajalein	1	10	8	10	10	10	10	9–	4/D	10
		2	9	8	10	10	9(E)	9(E)	7	2/D	8
		3	9	8	10	10	8(E)	9(E)			
		4	9–	8	10	10	8(E)	9(E)			
		5	8+	6	10	10	7(E)	8(E)			
	Kaneohe	1	10	6	10	10	10	10	8	6/MD[l]	9
		2	10	6	10	10	10	10	8–	4/MD	8
		3	9+	4	10	10	9(E)	10	7[e]	2/D	
		4	9+	4	10	10	9(E)	10			
		5	9–	4	10	10	9(E)	10			
	Port Hueneme	1	10	8	10	10	10	10	9	4/MD	10
		2	10	8	10	10	10	10	8	4/D	10
		3	10	6	10	10	10	10	7[e]	2/D	10
		4	10	6	10	10	10	10			
		5	10	6	10	10	10	10			
14	Kwajalein	1	9	6	10	10	6(E)	9	8	4/D	10
		2	8+	6	6/M	10	5(E)	9	6	2/D	8
		3	8	4	6/M	10	4(E)	6(E)			
		4	8	4	6/M	10	2(E)	5(E)			
		5	8–	4	6/M	8(E)	2(E)	4(E)			
	Kaneohe	1	9	6	10	10	9(E)	10	8	8/M	10
		2	9	4	6/F	10	8(E)	9(E)	8–	6/M	8
		3	8+	4	6/F(E)	10	6(E)	8(E)	7[e]	4/MD	6
		4	8+	4	6/F(E)	10	6(E)	8(E)			
		5	8+	4	6/F(E)	9(E)	5(E)	8(E)			
	Port Hueneme	1	10	8	10	10	10	10	9	4/M	10
		2	9+	8	10	10	8(E)	9(E)	8	2/M	10
		3	9	8	10	10	7(E)	8(E)	8–	2/D	10
		4	9	8	10	9(E)	6(E)	8(E)	7		
		5	9–	8	10	9(E)	6(E)	8(E)			

continued

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels[a]		
			Protection	Chalking	Blistering	Undercutting Edges	Rusting (Type) I	Rusting (Type) II	Protection	Blistering	Undercutting
14-R	Kwajalein	1	6	4	2/D	5(E)	2(E)	7	4	2-4/D	10
		2									
		3									
		4									
		5									
	Kaneohe	1	7	6	4/M	10	6(E)	6(E)	5	4/D	10
		2									
		3									
		4									
		5									
	Port Hueneme	1	10[d]	8	10	10	10	10	9	6/MD	10
		2	9	8	4/M	10	7(E)	8	8	4/MD	10
		3	8	8	2-4/D	10	2(E)	5	7	4/D	10
		4	7								
		5									

[a] Rating is at scribe.

[b] New failure.

[c] (E) represents "Edges failing."

[d] Failed at edges.

[e] Failed at scribe.

[f] Near edges.

[g] Edge blisters.

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NAVFACENGCOM - CHES DIV. Code 101 Wash, DC; Code 402 (R. Morony) Wash, DC; Code 403 (H. DeVoe) Wash, DC; Code 405 Wash, DC; Code FPO-1SP (Dr. Lewis) Wash, DC; Code FPO-IP12 (Mr. Scola), Washington DC; Contracts, ROICC, Annapolis MD; Scheessele, Code 402, Wash, DC
NAVFACENGCOM - LANT DIV.; Code 10A, Norfolk VA; Eur. BR Deputy Dir, Naples Italy; RDT&ELO 09P2, Norfolk VA
NAVFACENGCOM - NORTH DIV. AROICC, Brooklyn NY; CO; Code 09P (LCDR A.J. Stewart); Code 1028, RDT&ELO, Philadelphia PA; Code 111 (Castranovo) Philadelphia, PA; Code 114 (A. Rhoads); Design Div. (R. Masino), Philadelphia PA; ROICC, Contracts, Crane IN
NAVFACENGCOM - PAC DIV. Code 402, RDT&E, Pearl Harbor HI; Commander, Pearl Harbor, HI
NAVFACENGCOM - SOUTH DIV. Code 90, RDT&ELO, Charleston SC; Dir., New Orleans LA; ROICC (LCDR R. Moeller), Contracts, Corpus Christi TX
NAVFACENGCOM - WEST DIV. 102; 112; 408, San Bruno CA; AROICC, Contracts, Twentynine Palms CA; Code 04B; O9P/20; RDT&ELO Code 2011 San Bruno, CA
NAVFACENGCOM CONTRACT AROICC, Point Mugu CA; AROICC, Quantico, VA; Code 05, TRIDENT, Bremerton WA; Dir, Eng. Div., Exmouth, Australia; Eng Div dir, Southwest Pac, Manila, PI; OICC, Southwest Pac, Manila, PI; OICC/ROICC, Balboa Canal Zone; ROICC (Ervin) Puget Sound Naval Shipyard, Bremerton, WA; ROICC (LCDR J.G. Leech), Subic Bay, R.P.; ROICC LANT DIV., Norfolk VA; ROICC Off Point Mugu, CA; ROICC, Diego Garcia Island; ROICC, Keflavik, Iceland; ROICC, Pacific, San Bruno CA
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NAVMAG SCE, Guam
NAVMIRO OIC, Philadelphia PA
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NAVOCEANO Code 1600 Bay St. Louis, MS; Code 3432 (J. DePalma), Bay St. Louis MS
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NCBU 411 OIC, Norfolk VA
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NORDA Code 440 (Ocean Rsch, Off) Bay St. Louis, MS
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NSC Code 54.1 (Wynne), Norfolk VA
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NTC Code 54 (ENS P. G. Jackel), Orlando FL; Commander Orlando, FL; OICC, CBU-401, Great Lakes IL; SCE Great Lakes, IL
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